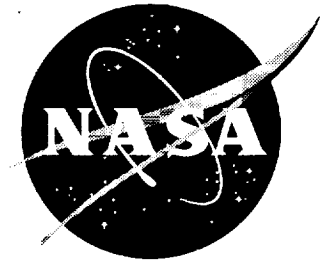


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Langley 8-Ft. HTT Test 139 Gas Analyses

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Abstract

This report presents results of gas analyses of Mach 7 Tunnel Calibration Test 139 conducted in the Langley 8-Ft. HTT from May through June of 1998. These tests in support of hypersonic airbreathing propulsion provided a current calibration at the primary test condition for the National Aero-Space Plane Concept Demonstration Engine and a new calibration for the two test conditions that will be used for engine testing in support of the Hyper-X program. Samples taken from three probes on the Flow Survey Apparatus were analyzed using mass spectrometers. Although this wind tunnel doesn't produce a true simulation of flight conditions, test results show that a uniform oxygen concentration of 21 percent was achieved.

Introduction

The NASA Langley 8-Ft. High Temperature Tunnel (8'-HTT) has been used to test flight structures under hypersonic conditions since 1968. It is a blow-down tunnel that burns methane and air in a high-pressure combustor. The products of combustion are expanded through a nozzle into the 8-foot diameter test section at a nominal Mach 7 velocity and issue out of the tunnel through an annular ejector, finally exiting to the atmosphere. This tunnel has been modified to facilitate the testing of hypersonic air-breathing propulsion systems, i.e., scramjets. A liquid oxygen storage and supply system was installed so that oxygen may be added to combustion air in order to bring the post-combustion oxygen level of the test medium up to 21 percent, simulating the oxidizing potential of air. Test 139, a series of tunnel runs conducted without test engine models, was undertaken to characterize spatial and temporal variations in tunnel test stream pressure, temperature, and oxygen concentration in order to provide a current calibration at the primary test condition for the National Aero-Space Plane Concept Demonstration Engine and a new calibration for the two test conditions that will be used for engine testing in support of the Hyper-X program. A uniform distribution of pressure, temperature, and oxygen is required over a rectangular area corresponding to the intake area of the scramjet engine, though it is not expected that this tunnel medium is a true simulation of flight conditions since gross amounts of water and carbon dioxide are also present. Temporal and spatial plots of mass spectrometric data for each run are presented in the Appendix following a description of the test apparatus, a section on mass spectrometer data reduction, and the conclusion.

Apparatus

A diagram of one leg of the system is shown in figure 1. Rotary-vane roughing pumps located at the system rack just outside the test section pull the tunnel test samples through approximately 40 feet of 0.25 inches diameter tubing. Sample cylinders were used to collect 10-second gas samples for three tunnel runs but gas chromatographic analysis determined there were air leaks in this part of the system. These leaks did not affect the mass spectrometer readings however.

Mass Spectrometers

Three quadrupole mass spectrometers (MS#0, MS#1, & MS#2) provide time plots of ion currents of nitrogen, oxygen, carbon dioxide, nitric oxide, and argon during each tunnel run. 600 points of data were recorded for each of these five species in each mass spectrometer buffer during the run. These 3000 data points from each of the three mass spectrometers are transferred to data acquisition computer after the run

for storage and subsequent data reduction. A sampling rate of 5 per second was used to provide two-minute plots for each run. Ion currents were converted to partial pressures based on calibration curves generated by sampling calibration gases through a range of pressures. Mole fractions are calculated by dividing the partial pressure of a given species by the sum of the partial pressures of all measured species.

Mass Spectrometer Calibration

Two calibrations were carried out about 15 minutes after each tunnel run. Each gas mixture was simultaneously sampled through the mass spectrometers for two minutes while a hand valve was slowly turned to increase the sample pressures as measured by pressure transducers. Two pressurized gas mixtures were used: one containing 63.99% nitrogen, 25.00% oxygen, 10.00% carbon dioxide, and 1.01% argon; and a separate mixture containing 2.02% nitric oxide with a balance of nitrogen. Each calibration was used to produce a least-squares fit of partial pressure versus ion current for each species.

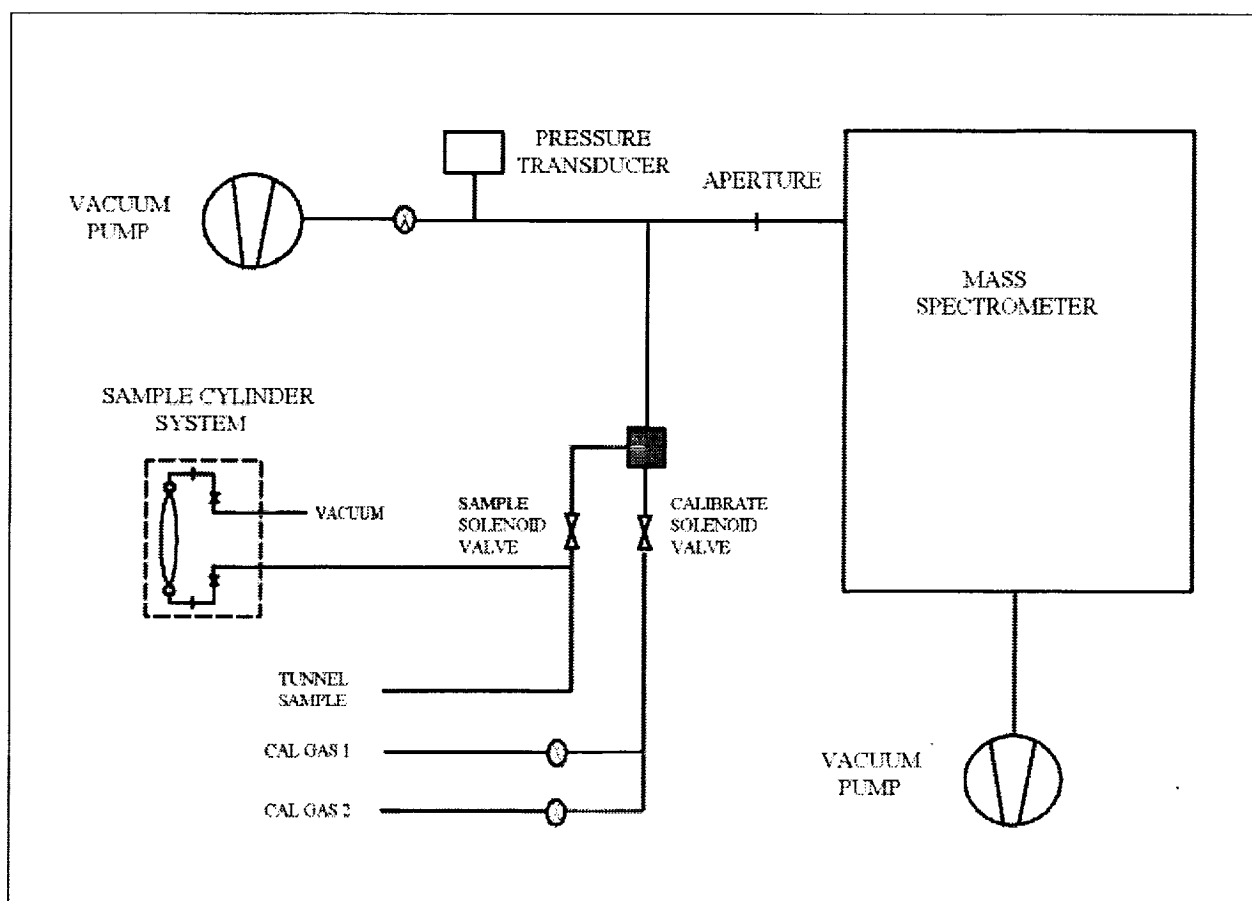


Figure 1. System Schematic

Mass Spectrometer Data Reduction

The partial pressure of a species, P_i , can be expressed as

$$P_i = a_i (I_i)^{b_i}$$

where I_i is the mass spectrometer ion current of the species, and a_i and b_i are least-squares regression coefficients generated from calibrations of ion currents with gas mixtures at several sample pressures. The geometric form of this expression allows for some degree of nonlinearity in mass spectrometer response.

The mole fraction of a species, X_i , is given by

$$X_i = \frac{P_i}{P_{N_2} + P_{O_2} + P_{Ar} + P_{CO_2} + P_{NO} + P_{H_2O}} \pm U_{X_i}$$

where U_{X_i} is the uncertainty in X_i . Partial pressures of N_2 , O_2 , Ar , NO , and CO_2 are calculated directly from the ion currents, and the partial pressure of H_2O is taken as twice that of CO_2 . (This equation assumes all species are accounted for ($\sum X_i = 1$), although CO and various other oxides of nitrogen may also be present.)

The uncertainty in the mole fraction of a species, U_{X_i} , is given by¹

$$U_{X_i} = \sqrt{\left(\frac{\partial X_i}{\partial P_{N_2}} U_{P_{N_2}}\right)^2 + \left(\frac{\partial X_i}{\partial P_{O_2}} U_{P_{O_2}}\right)^2 + \left(\frac{\partial X_i}{\partial P_{Ar}} U_{P_{Ar}}\right)^2 + \left(\frac{\partial X_i}{\partial P_{CO_2}} U_{P_{CO_2}}\right)^2 + \left(\frac{\partial X_i}{\partial P_{NO}} U_{P_{NO}}\right)^2 + \left(\frac{\partial X_i}{\partial P_{H_2O}} U_{P_{H_2O}}\right)^2}$$

¹ Coleman, Hugh W.; and Steele, W. Glenn, Jr.: *Experimentation and Uncertainty Analysis for Engineers*. John Wiley & Sons, Inc., 1989, p. 42.

The uncertainty in the partial pressure of a species, U_{P_i} , is given by

$$U_{P_i} = \sqrt{\epsilon_{c_i}^2 + \epsilon_{s_i}^2}$$

where ϵ_{c_i} , the calibration contribution to the partial pressure uncertainty, is twice the standard error of the partial pressure regression estimate from the calibration, and ϵ_{s_i} , the ion current stability contribution to the partial pressure uncertainty, is a function of the stability of the ion current output, given by

$$\epsilon_{s_i} = a_i (SI_i)^{b_i}$$

where S is the stability (precision error) of the ion currents, I_i , and a_i & b_i the regression coefficients. Twice the manufacturer's specification of 2 percent for S , i.e., 0.04, is used in all cases. By using twice the standard error of the partial pressure estimate and twice the stability specification, a 95% uncertainty interval is generated about X_i .

By way of example, for the case of nitrogen, X_{N_2} is given by

$$X_{N_2} = \frac{P_{N_2}}{P_{N_2} + P_{O_2} + P_{Ar} + P_{CO_2} + P_{NO} + P_{H_2O}} \pm U_{X_{N_2}}$$

The uncertainty in the mole fraction of nitrogen, $U_{X_{N_2}}$, is given by

$$U_{X_{N_2}} = \sqrt{\left(\frac{\partial X_{N_2}}{\partial P_{N_2}} U_{P_{N_2}}\right)^2 + \left(\frac{\partial X_{N_2}}{\partial P_{O_2}} U_{P_{O_2}}\right)^2 + \left(\frac{\partial X_{N_2}}{\partial P_{Ar}} U_{P_{Ar}}\right)^2 + \left(\frac{\partial X_{N_2}}{\partial P_{CO_2}} U_{P_{CO_2}}\right)^2 + \left(\frac{\partial X_{N_2}}{\partial P_{NO}} U_{P_{NO}}\right)^2 + \left(\frac{\partial X_{N_2}}{\partial P_{H_2O}} U_{P_{H_2O}}\right)^2}$$

$$\frac{\partial X_{N_2}}{\partial P_{N_2}} = \frac{\sum P_i - P_{N_2}}{\sum^2 P_i}$$

$$\frac{\partial X_{N_2}}{\partial P_{O_2}} = \frac{-P_{N_2}}{\sum^2 P_i}$$

$$\frac{\partial X_{N_2}}{\partial P_{Ar}} = \frac{-P_{N_2}}{\sum^2 P_i}$$

$$\frac{\partial X_{N_2}}{\partial P_{CO_2}} = \frac{-P_{N_2}}{\sum^2 P_i}$$

$$\frac{\partial X_{N_2}}{\partial P_{H_2O}} = \frac{-P_{N_2}}{\sum^2 P_i}$$

Thus the uncertainty in the mole fraction of nitrogen, $U_{X_{N_2}}$, is given by

$$U_{X_{N_2}} = \frac{1}{\sum P_i} \sqrt{\left[\left(\sum P_i - P_{N_2} \right) U_{P_{N_2}} \right]^2 + \left(P_{N_2} U_{P_{O_2}} \right)^2 + \left(P_{N_2} U_{P_{Ar}} \right)^2 + \left(P_{N_2} U_{P_{CO_2}} \right)^2 + \left(P_{N_2} U_{P_{NO}} \right)^2 + \left(P_{N_2} U_{P_{H_2O}} \right)^2}$$

Mole fraction uncertainties for the other species, U_{X_i} , are found in like manner.

Plots of mole fractions with errors show the uncertainty interval varying about the mole fraction for each species. Uncertainties are at their greatest in regions of low sample pressure ($\sum P_i \rightarrow 0$), e.g., when the sample probes traverse beyond the outer boundary of the tunnel stream during the run. Another important determinant of mole fraction uncertainty is the standard error of the partial pressure estimate generated from the least-squares regression of partial-pressure-versus-intensity from calibration.

Unaccounted-for Sources of Mass Spectrometer Error

The above treatment is not an inclusive analysis of all possible sources of error in MS mole fraction measurements. Other sources of error may include but are not limited to:

1. Calibration gas bias. Pressurized gas mole fraction uncertainties are 1% of the quoted value for each component.
2. Calibration pressure transducer error. This is the pressure transducer used to measure sample pressures during calibration, the error of which is on the order of 1%.
3. Sample probe/line contamination. Flow Survey Apparatus surfaces are subjected to extremely high levels of heating during the sweep. This intense heat could conceivably effect a change in the composition of the sample but most likely much less than 1% of the measured mole fraction for each species.
5. Mole fractions of H_2O are taken as twice those of CO_2 . This assumes that the sole source of H_2O is the complete combustion of methane and oxygen, *i.e.*, $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. This will be in error if the methane is contaminated with other combustible gases such as propane, ethane, etc., or if H_2O is present in any of the gases used in the operation of the tunnel (methane, air, LOX).
6. Temporal uncertainty. The mass spectrometers operate independently of the tunnel data system. The two may be shifted in time with respect to each other by as much as 1 second. Likewise, transit times from the sample inlet on the FSA to the location of the mass spectrometers are on the order of 1 to 5 seconds.

Test Results

Gas samples for all tunnel runs were acquired using three of four gas sample probes attached to the side of the FSA. The FSA sweeps through the tunnel stream during each run and acquires temperature and pressure profiles from several probes along its length. Gas sample probe locations were 7.5 inches above, 1.5 inches above, and 1.5 inches below, below the tunnel stream centerline (with the FSA in the vertical position).

Mass Spectrometer Plots

Plots of data from the FSA sweep portion of each run are compiled in the Appendix in the following sequence:

- 1. FSA Angular Position Data:** This shows the angular position of the FSA versus tunnel run time.
- 2. Mole Fractions:** Mole fractions of N_2 , O_2 , Ar, CO_2 , NO, and H_2O , where each mole fraction, X_i , is equal to the calculated partial pressure of a given species divided by the sum of all partial pressures. Partial pressure of H_2O is taken as twice that of CO_2 . A CO_2 fragmentation coefficient of 0.0817 was used in all cases.
- 3. Mole Fractions w/Errors, O_2 .** Plots of O_2 mole fractions with error bands. Errors for a given species are a function of all measured partial pressures, the standard error of the least-squares fit of the given species, and the inherent stability (precision error) of the mass spectrometer outputs (see "Mass Spectrometer Data Reduction" section). The error bands are defined for the ion current range generated in calibration, which is nominally taken as one half to twice the average ion current measured during the FSA sweep. Consequently, errors for each species are shown only where all ion currents are within their respective calibration ranges. This provides an indication of where and to what degree the mole fractions may be accepted as accurate.
- 4. Mole Fractions w/Errors, N_2 .**
- 5. Mole Fractions w/Errors, CO_2 & NO.**
- 6. Mole Fractions w/Errors, Ar & H_2O .**
- 7. Mole Fractions vs. FSA Position:** Mole fractions of all measured species as a function of the angular position of the FSA. This provides an indication of the degree of spatial uniformity of each species across the tunnel stream.
- 8. Mole Fractions vs. FSA Position w/Errors, O_2 .**
- 9. Mole Fractions vs. FSA Position w/Errors, CO_2 & NO.**
- 10. Mole Fractions vs. FSA Position w/Errors, Ar & H_2O .**

Conclusion

Hypersonic airbreathing engines need a uniform oxygen distribution of 21% across their intake area in order to operate properly. Although the test stream of the 8-Ft. HTT nominally has gross amounts of water vapor and carbon dioxide as well as small amounts of other non-atmospheric gases and is thus not a true simulation of flight conditions, results from Test 139 show that all constituents are uniformly distributed. Temporal and spatial plots of mass spectrometric data for each run of Test 139 show that test section oxygen mole fractions reach 21% at or before 140 seconds into each run and remain so until normal stop. These gas analyses thus verify the attainment of a realistic oxygen profile in the test stream the 8-Ft. HTT.

Appendix:

Mole Fraction Plots

Test 139 Run 4

Combustor Pressure: 2000 psia

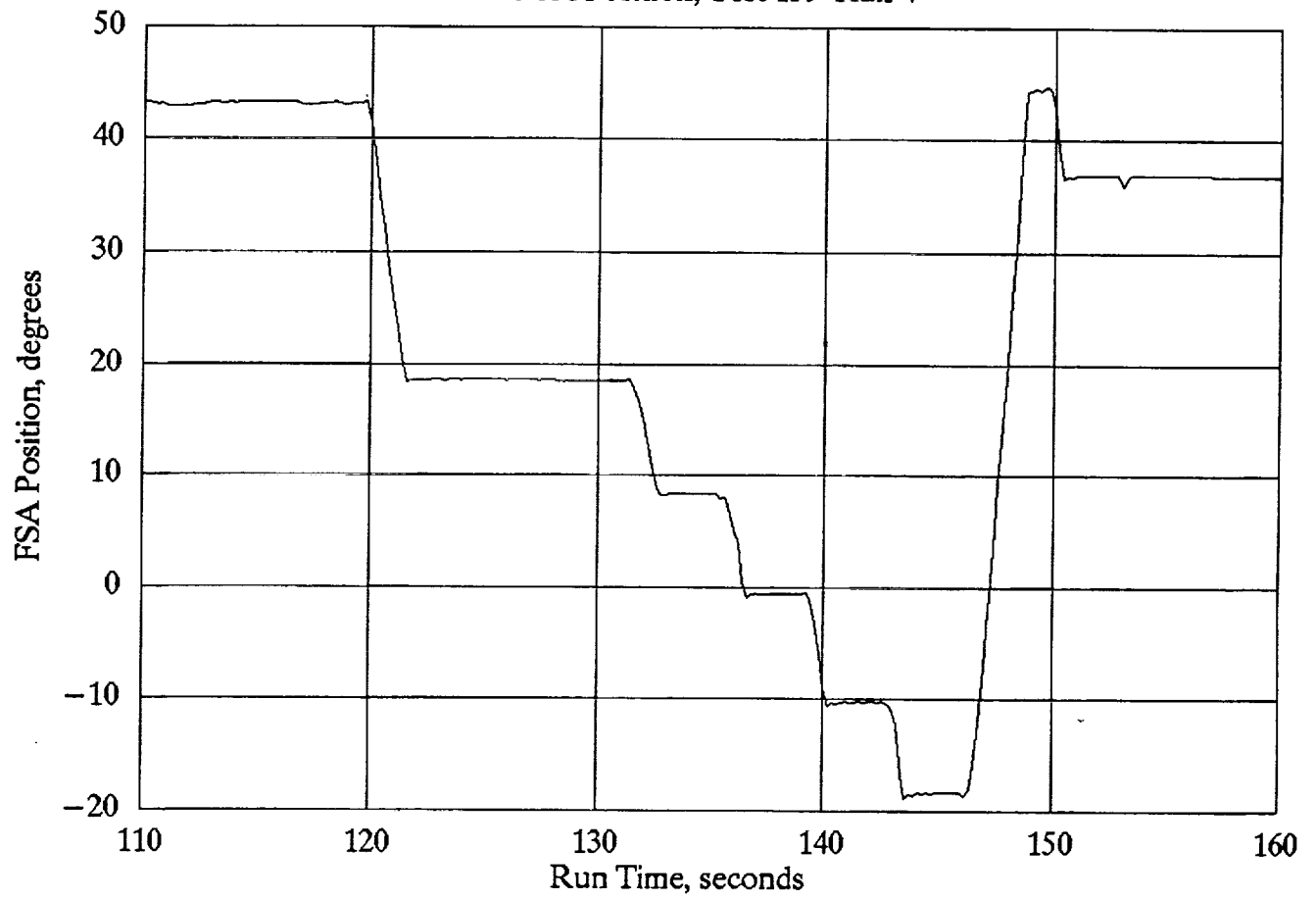
Combustor Temperature: 3300 R

Normal Stop: 150.1 seconds

Probes: FSA+7.5, FSA+1.5

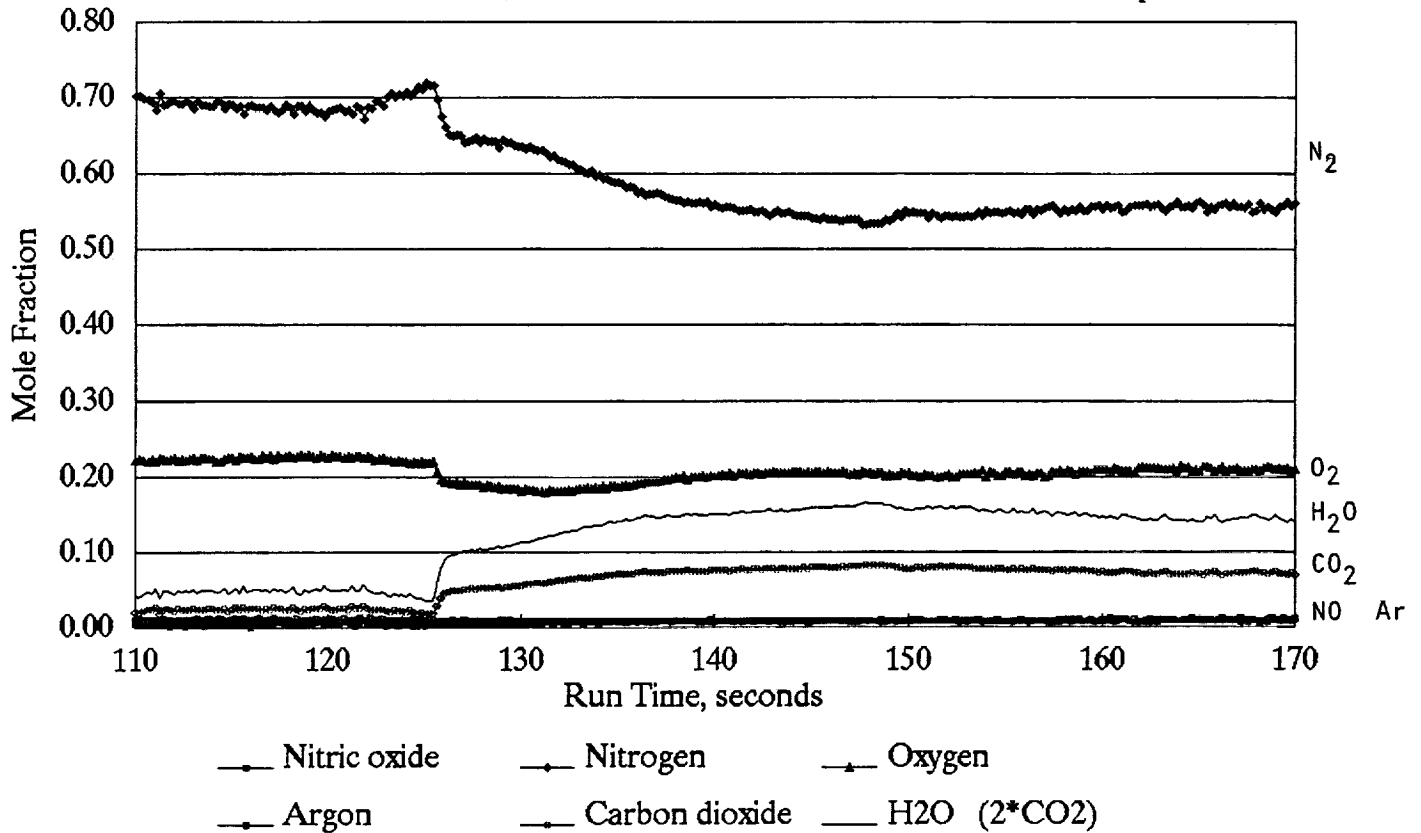
8' HTT Gas Analysis System

FSA Position, Test 139 Run 4



8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions, FSA Sweep



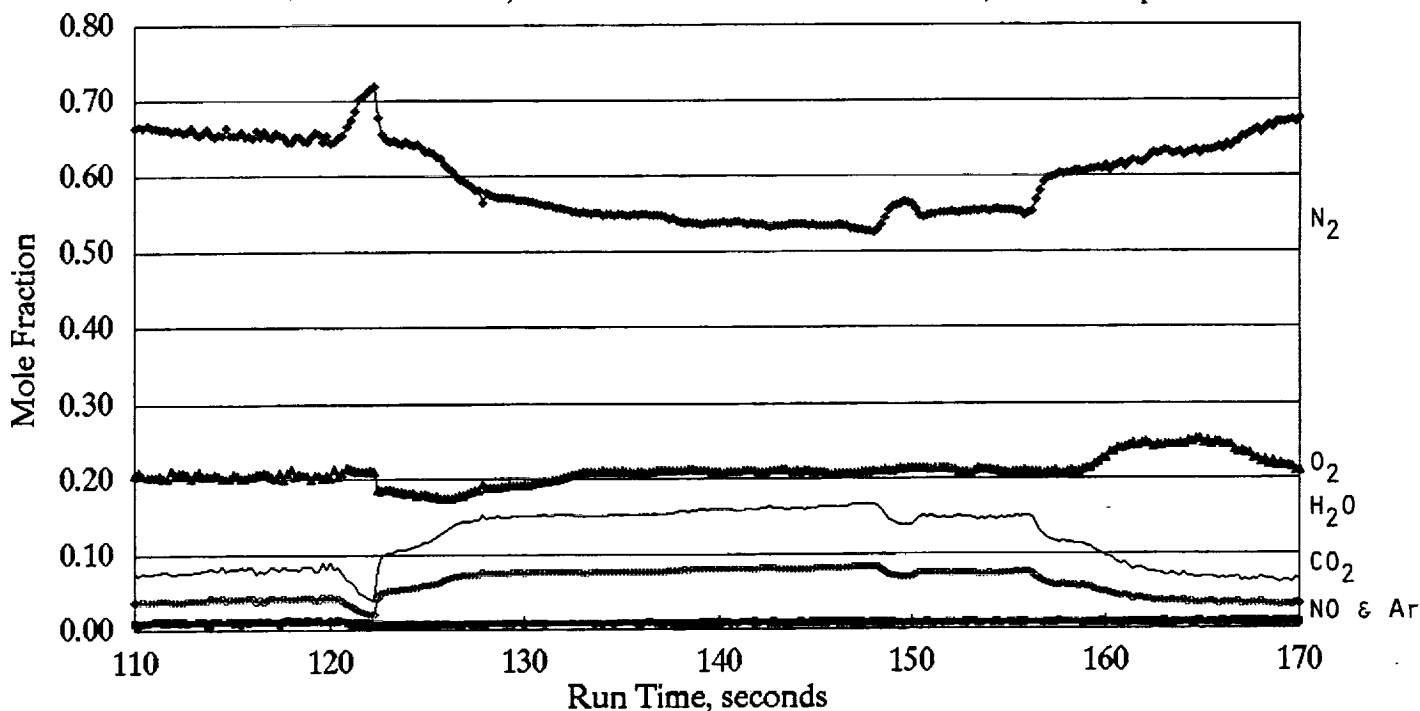
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.560	+/-	0.019
Oxygen:	0.199	+/-	0.013
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.075	+/-	0.007
H2O:	0.150	+/-	0.012
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

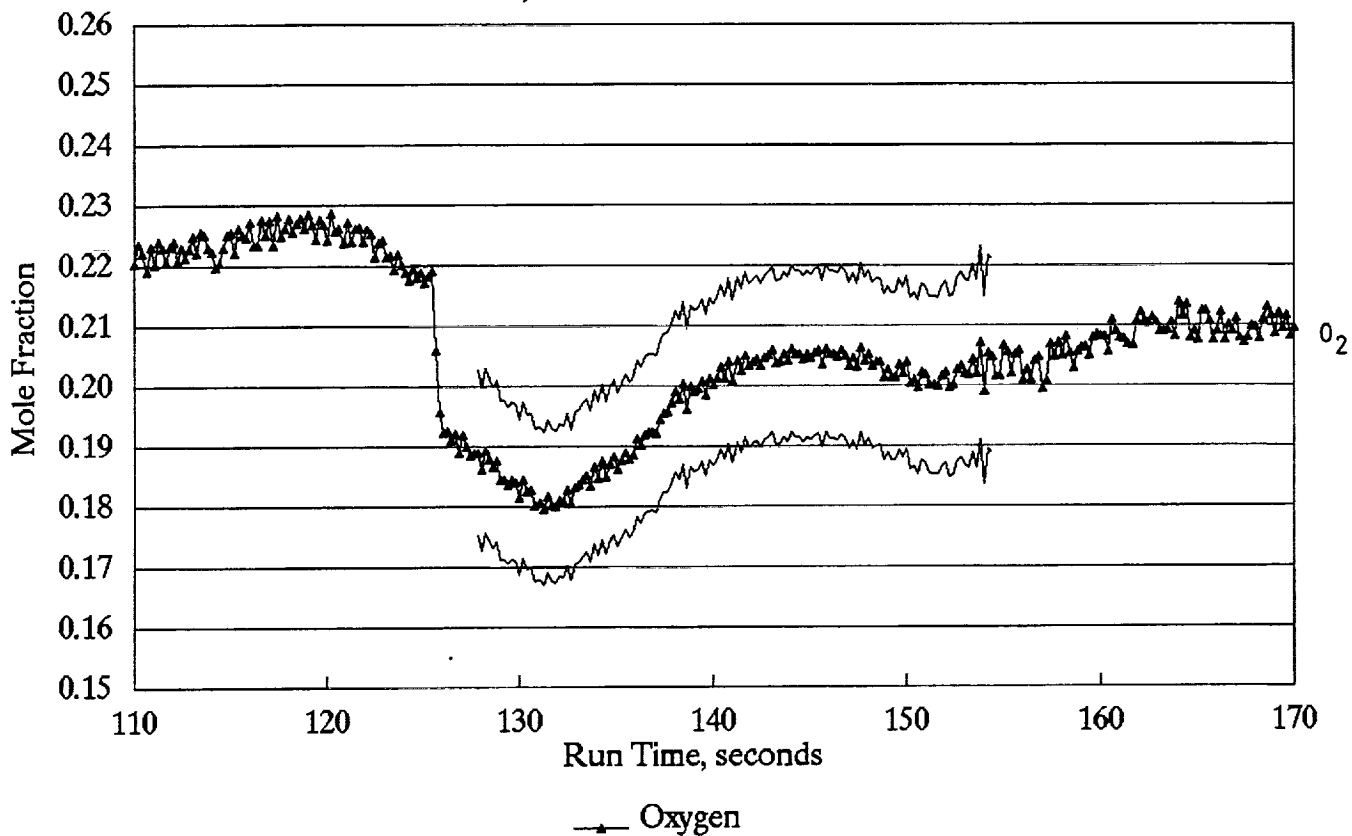
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.540	+/-	0.026
Oxygen:	0.209	+/-	0.019
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.079	+/-	0.008
H ₂ O:	0.157	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

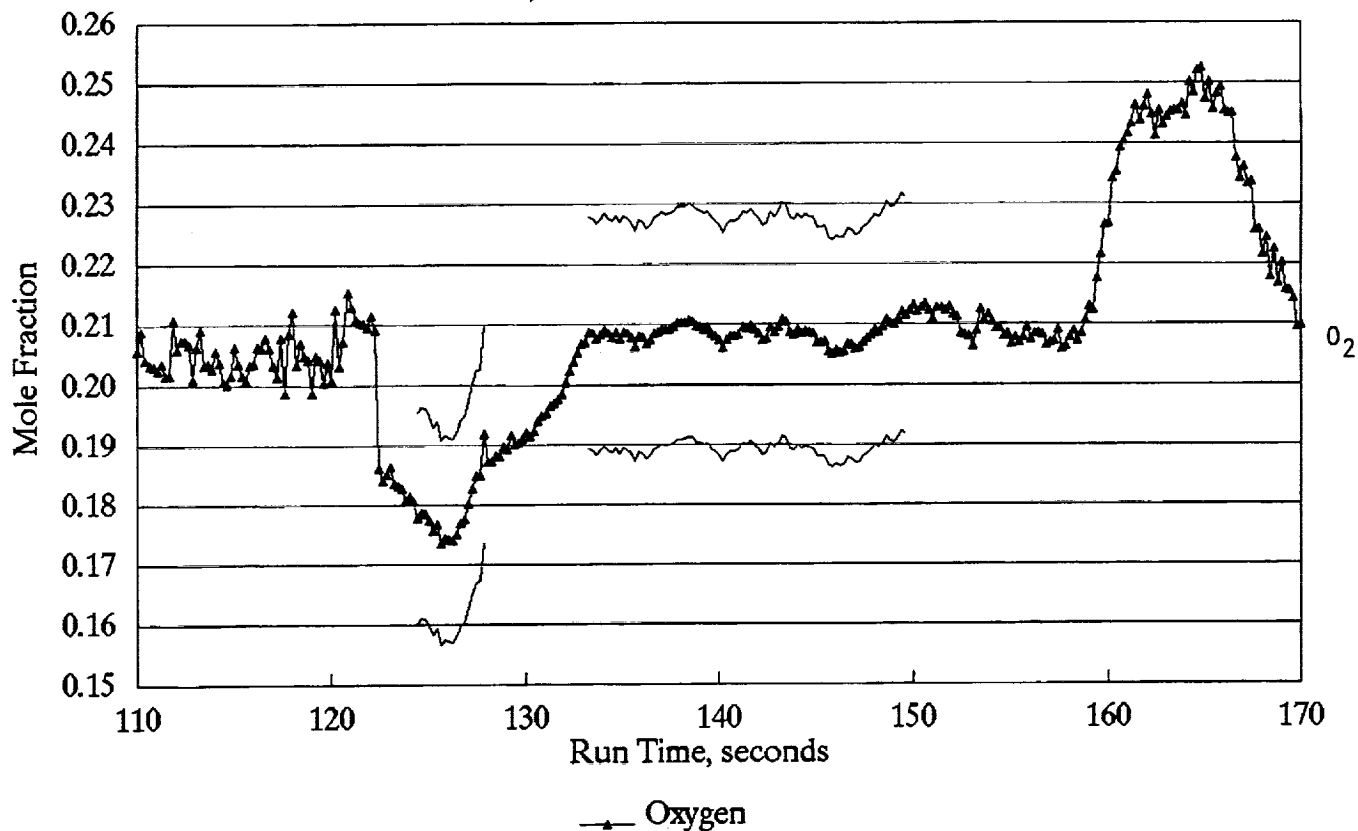
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.199 +/- 0.013

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

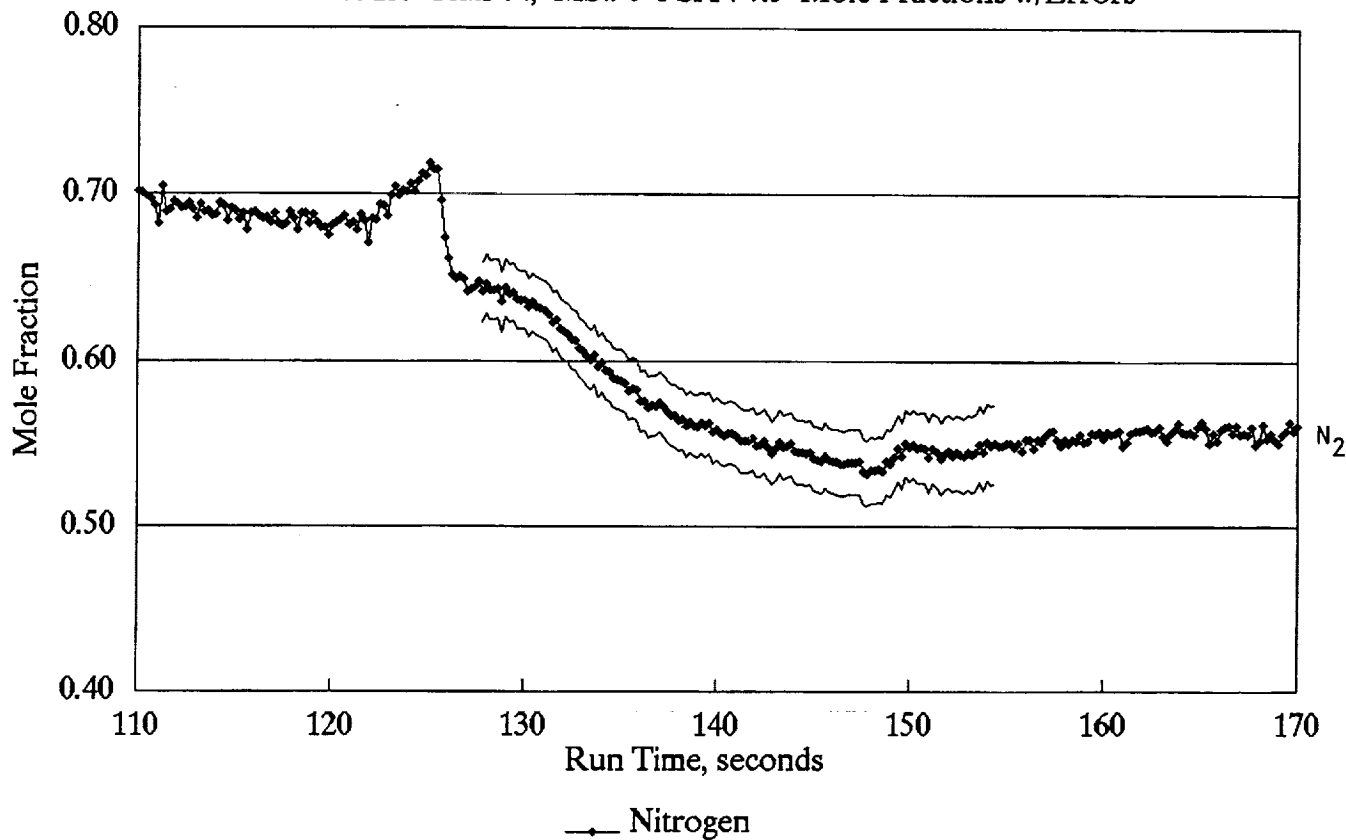
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.209 +/- 0.019

8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

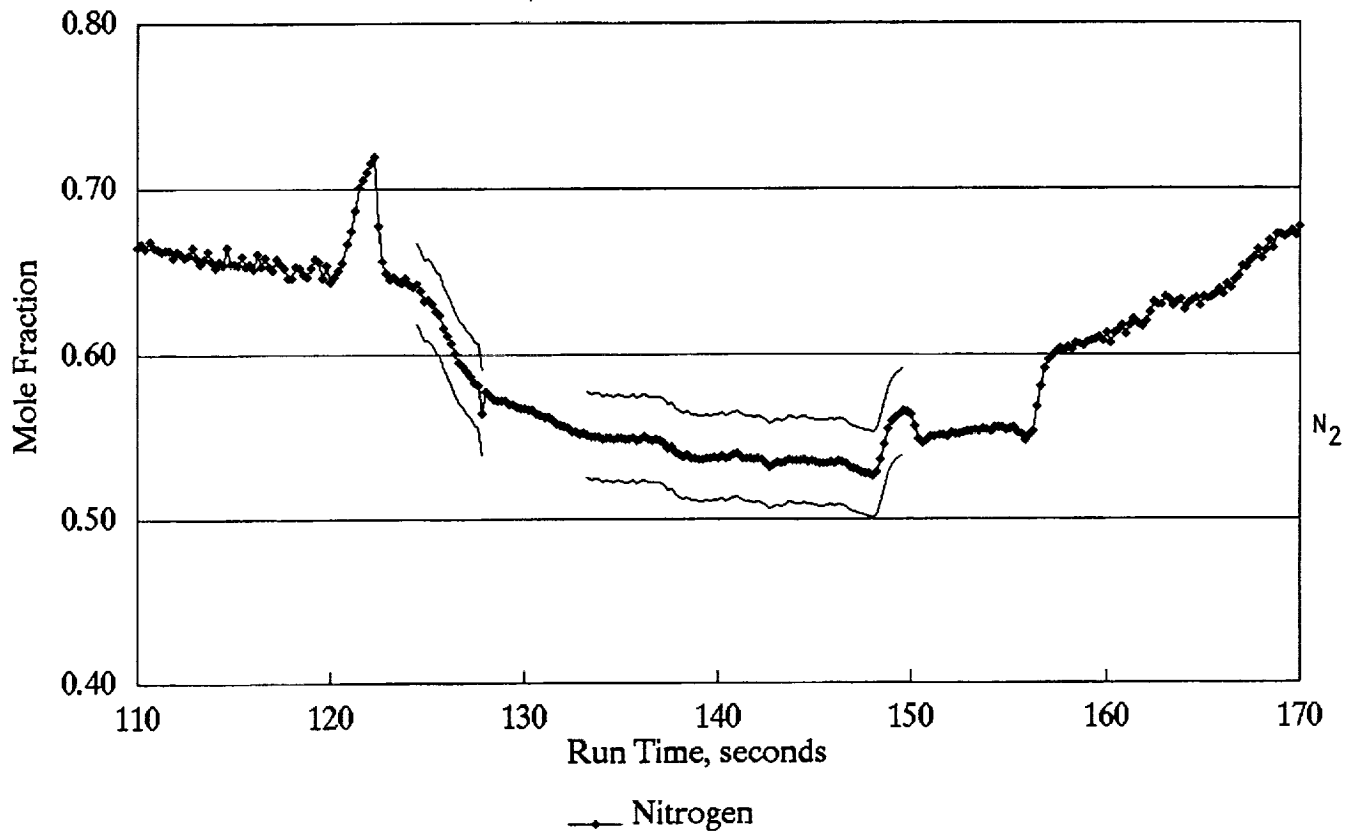
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen: 0.560 +/- 0.019

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

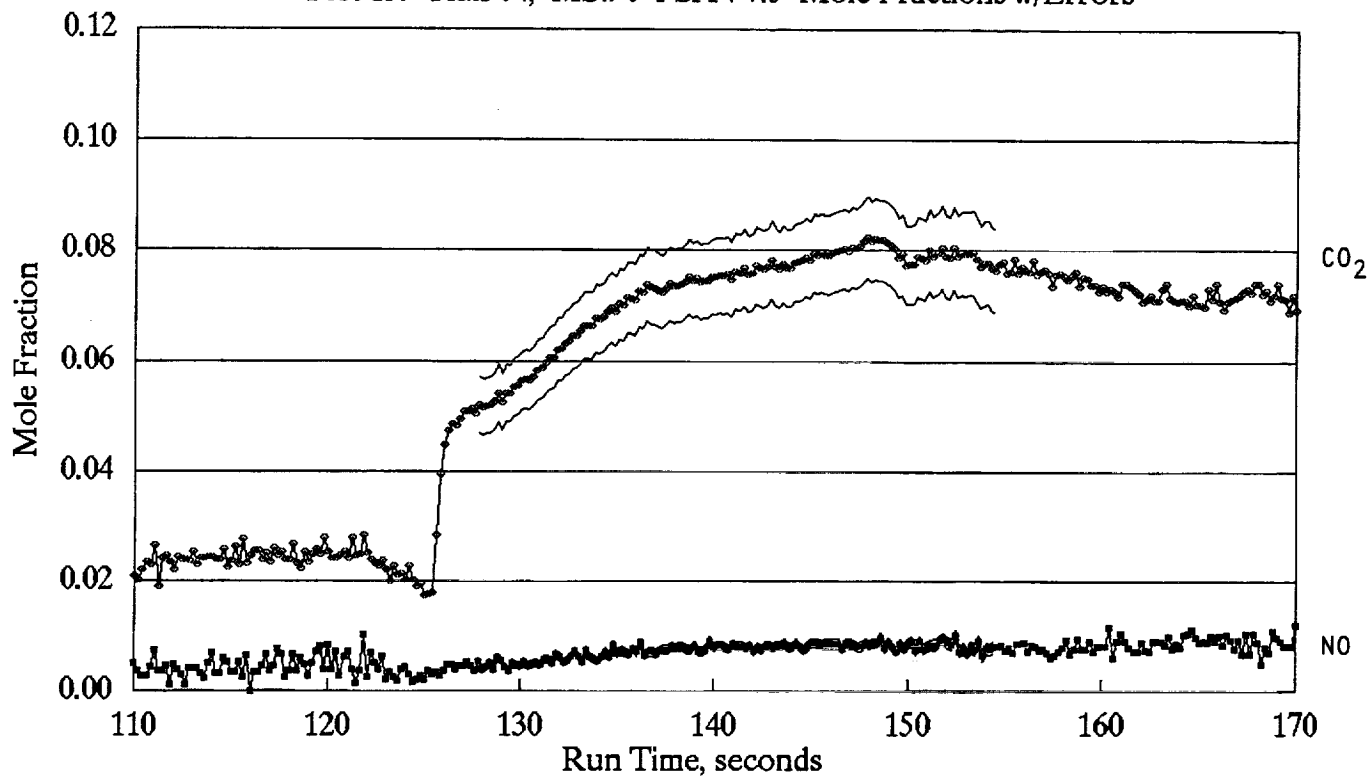
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen: 0.540 +/- 0.026

8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

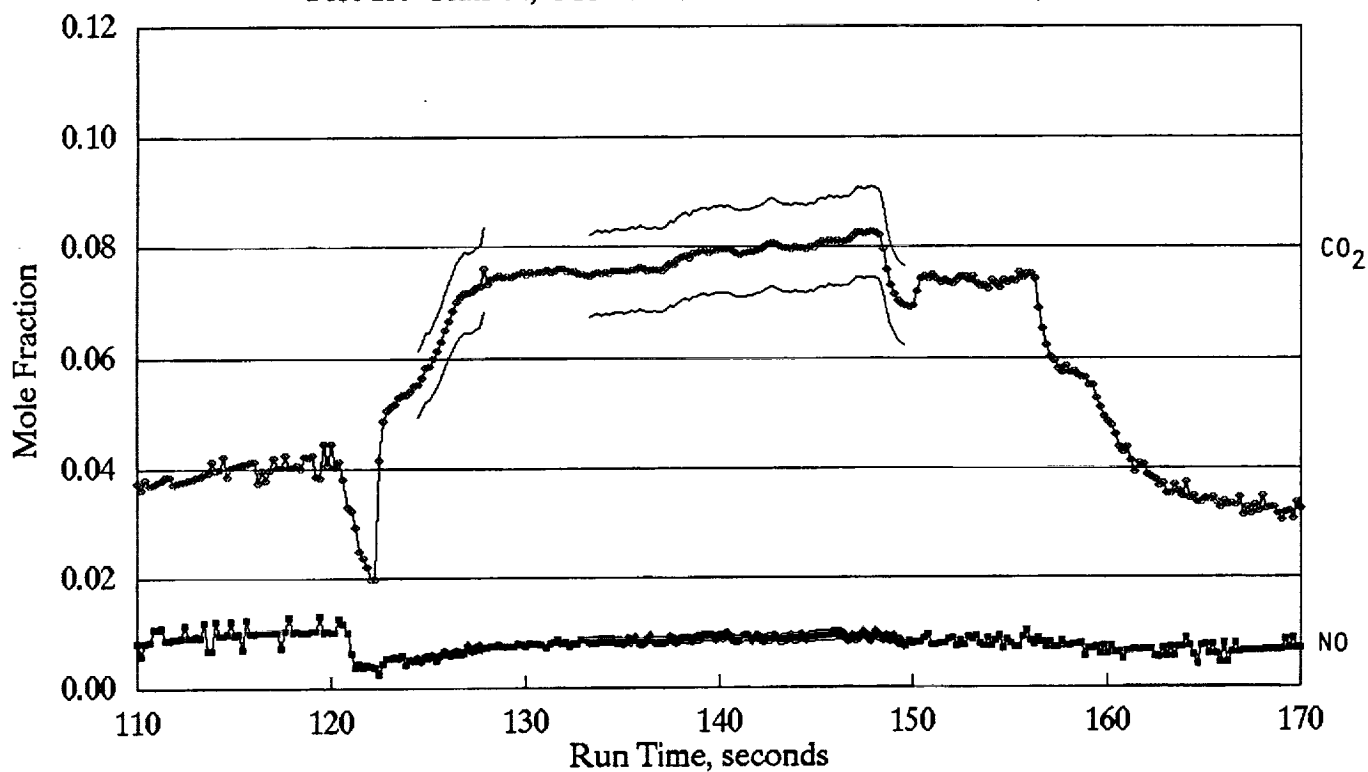
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.075	+/-	0.007
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

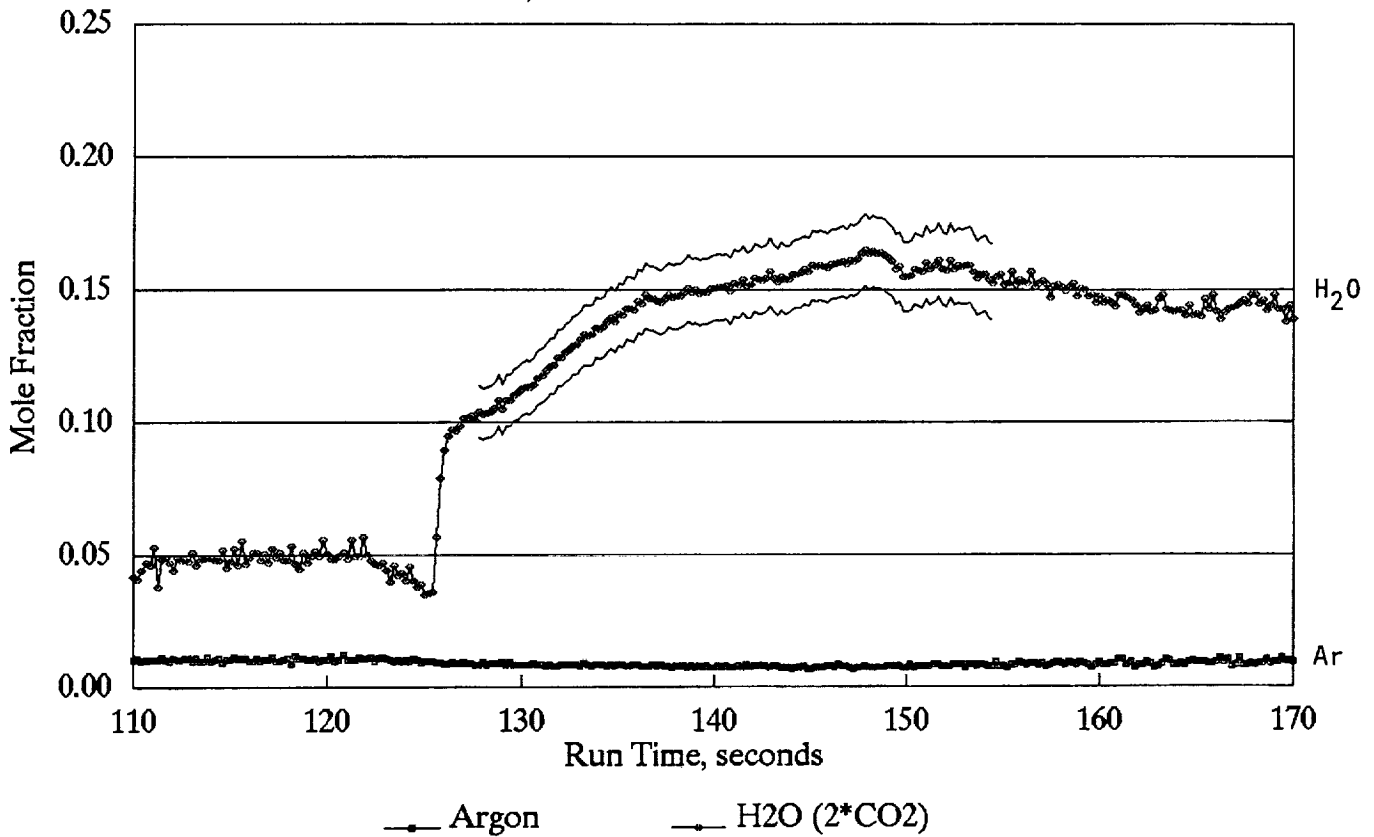
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.079	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

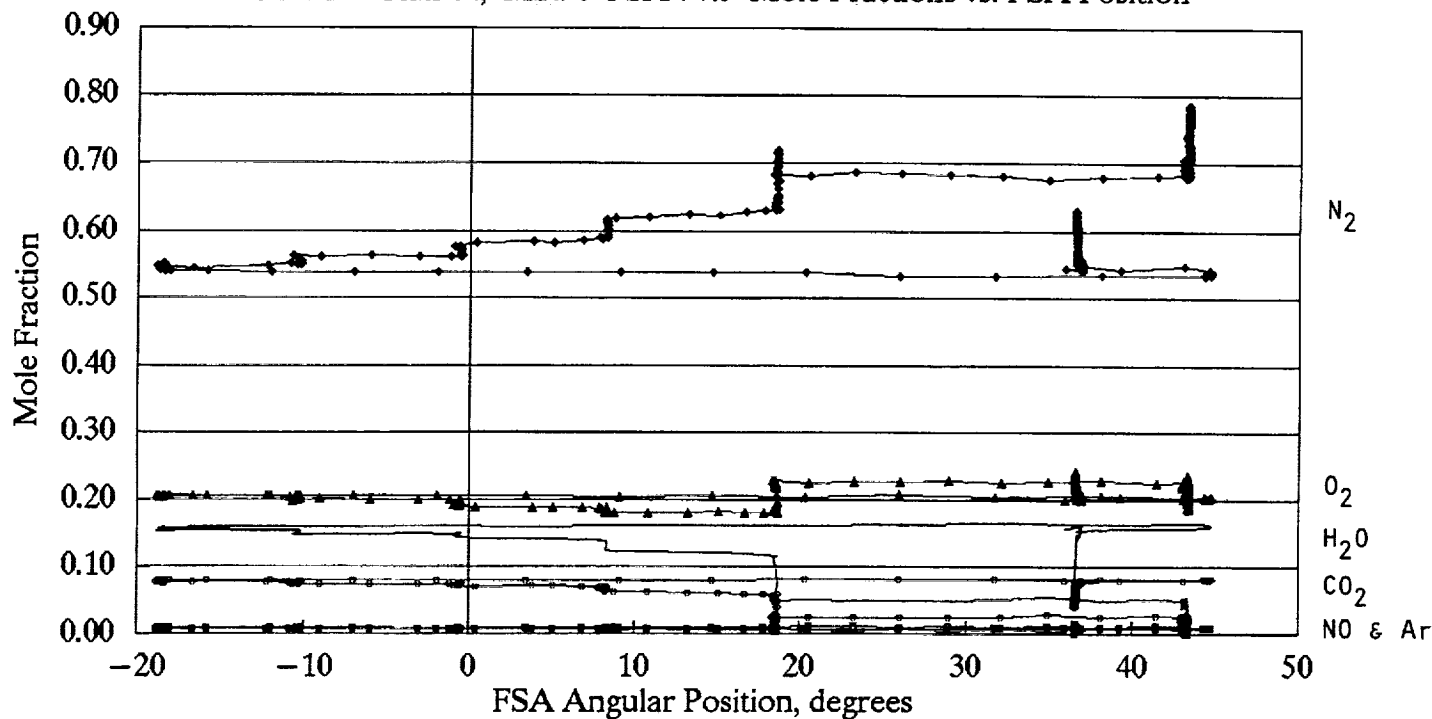
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.150	+/-	0.012

8' HTT Gas Analysis System

Test 13 Run 04, MS#0 FSA+7.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

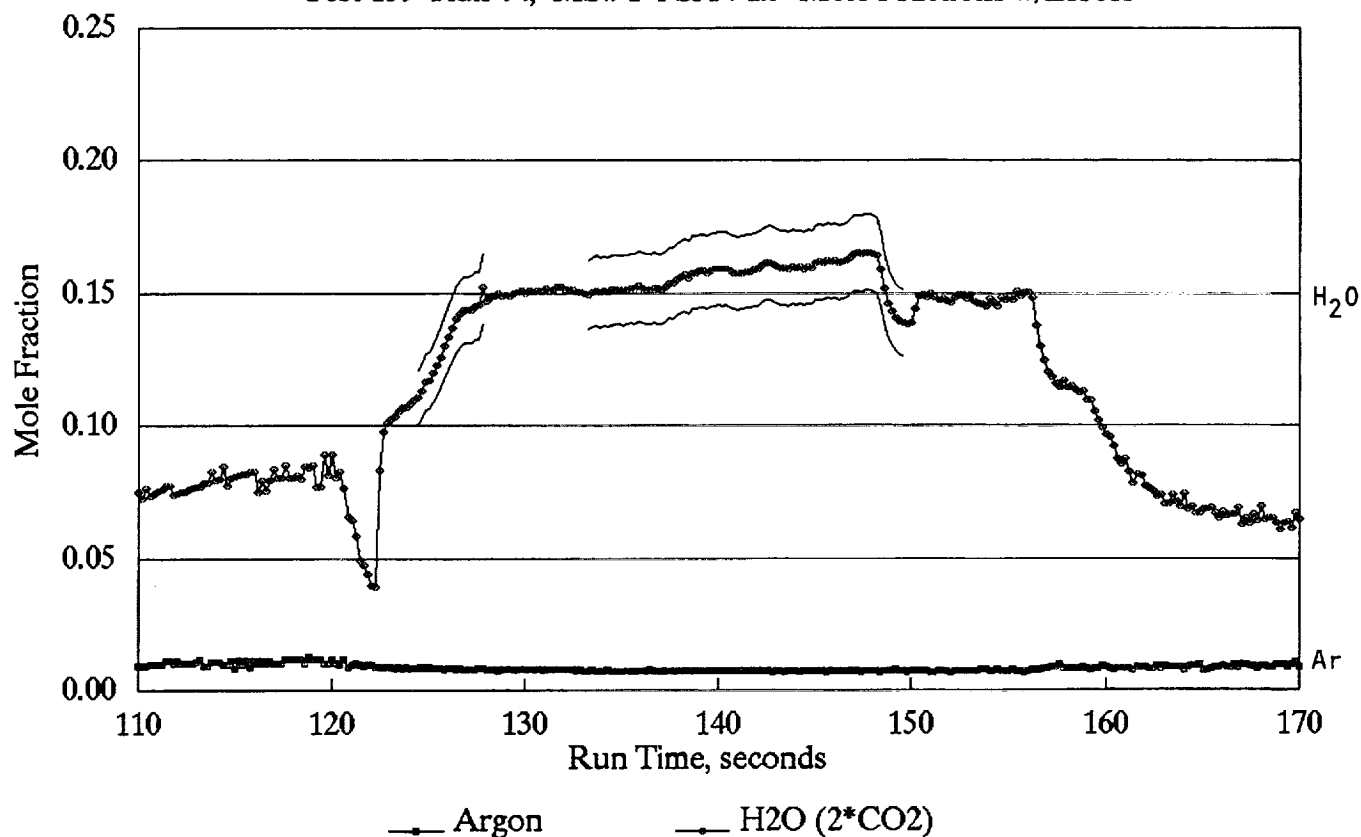
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.560	+/-	0.019
Oxygen:	0.199	+/-	0.013
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.075	+/-	0.007
H2O:	0.150	+/-	0.012
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

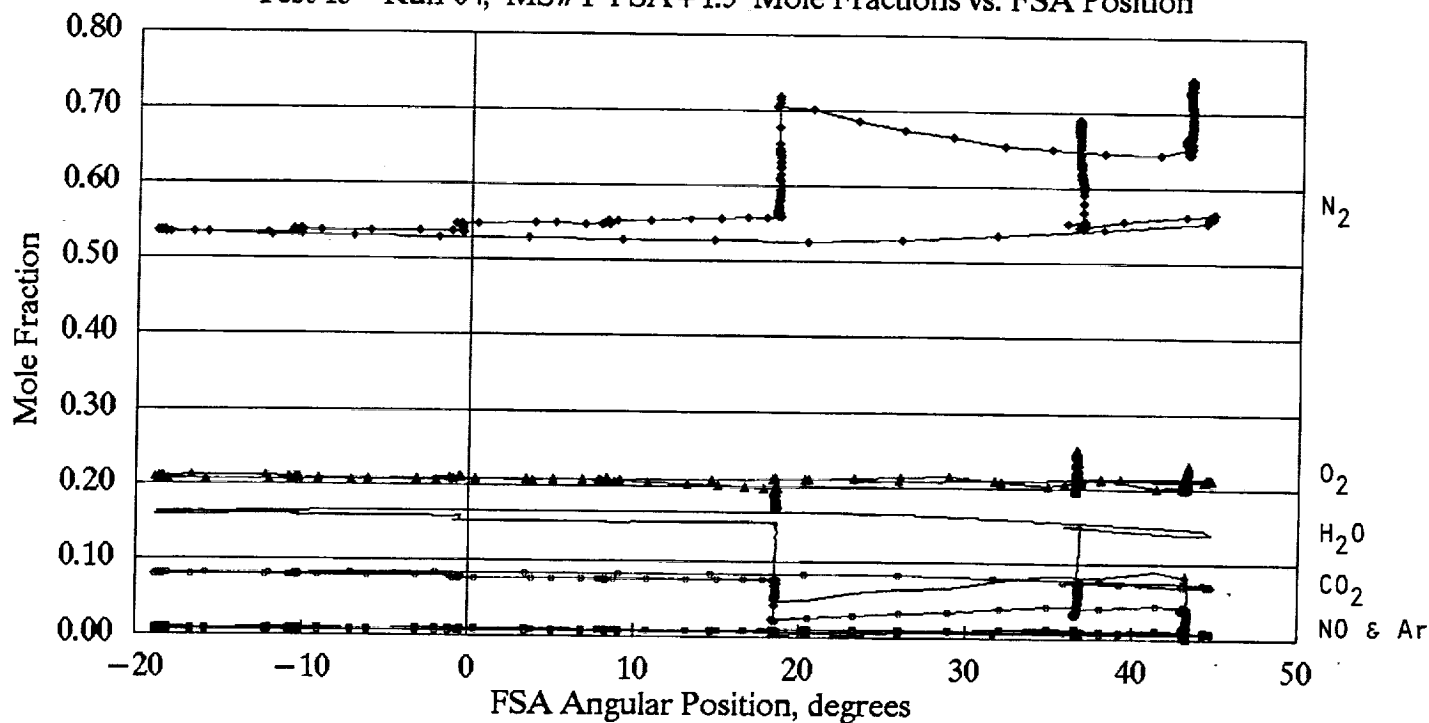
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.157	+/-	0.014

8' HTT Gas Analysis System

Test 13 Run 04, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



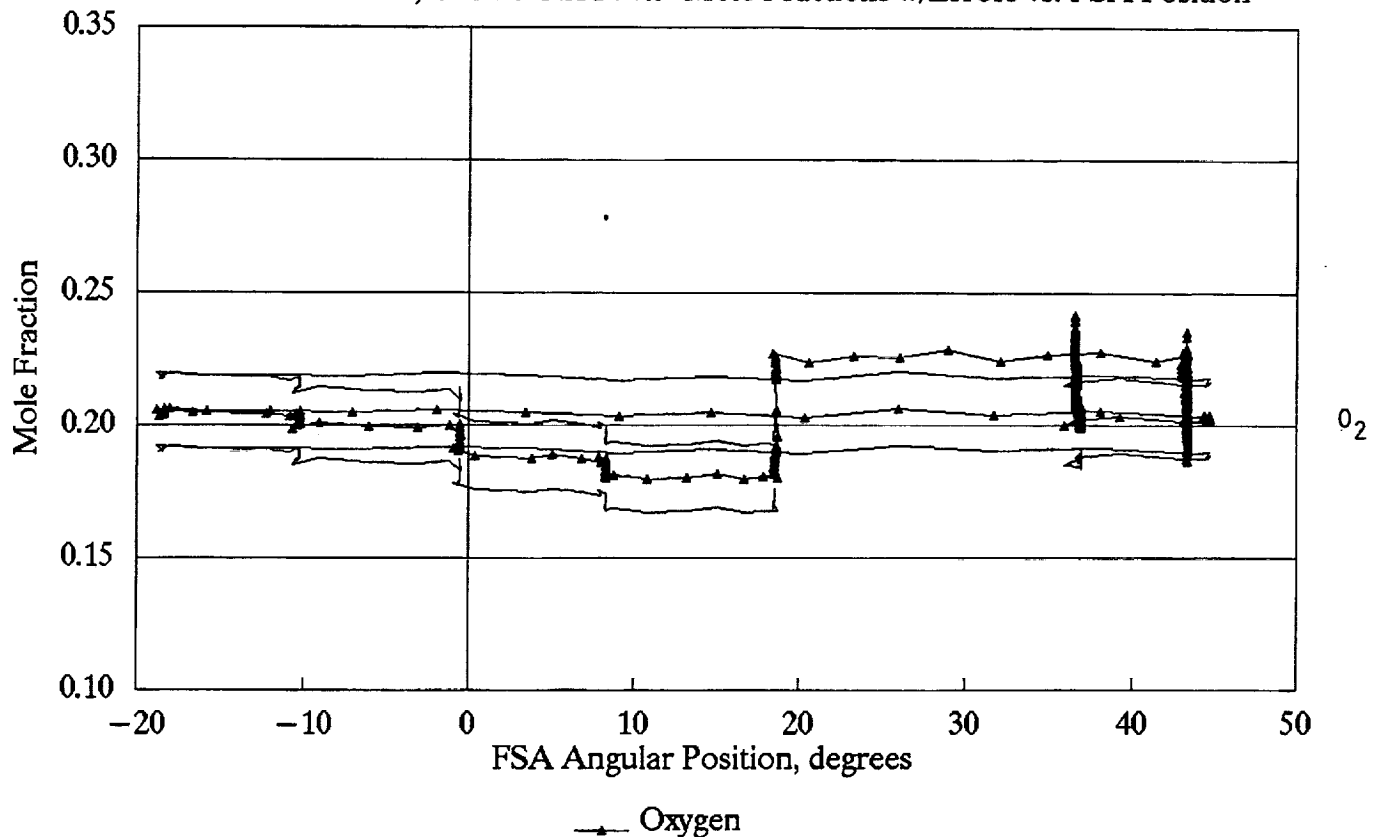
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.540	+/-	0.026
Oxygen:	0.209	+/-	0.019
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.079	+/-	0.008
H2O:	0.157	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

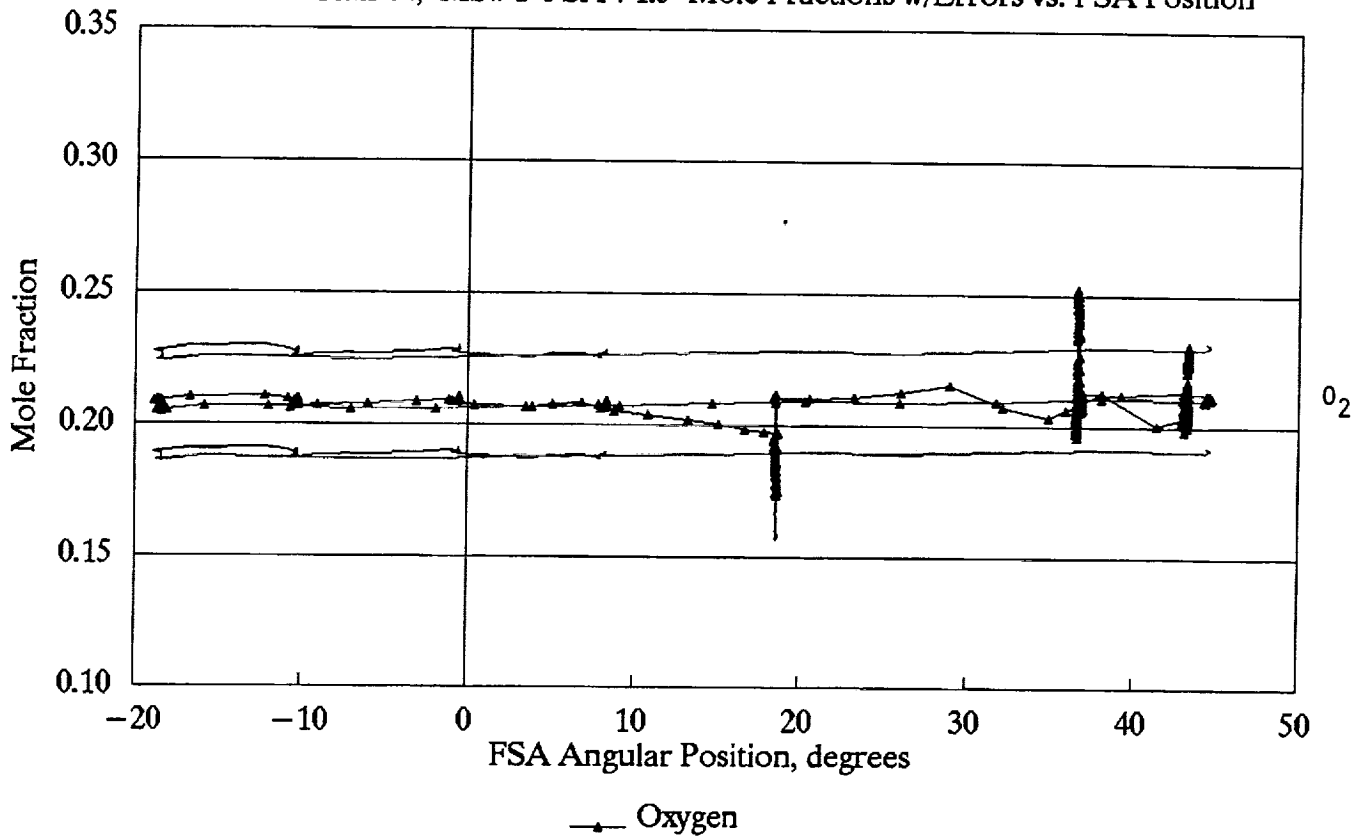
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.199 +/- 0.013

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

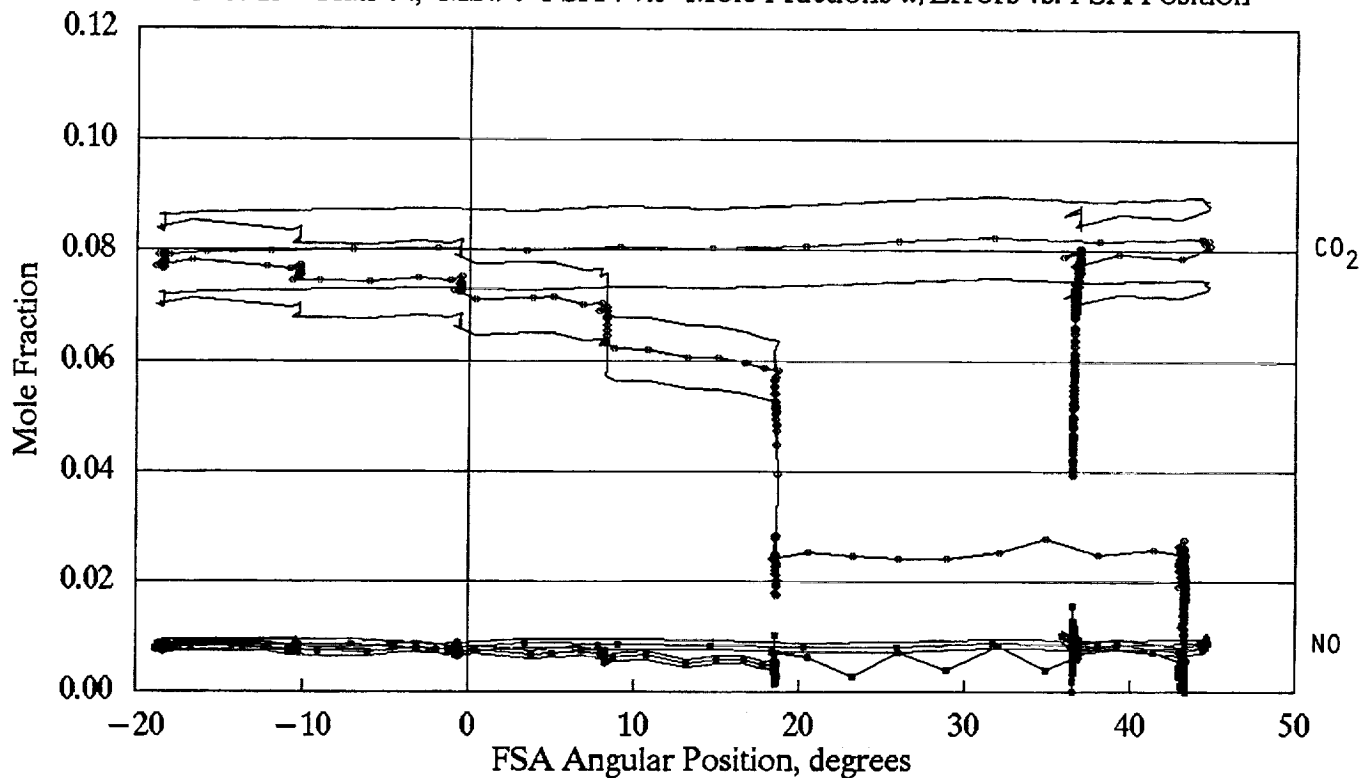
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.209 +/- 0.019

8' HTT Gas Analysis System

Test 13⁹ Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

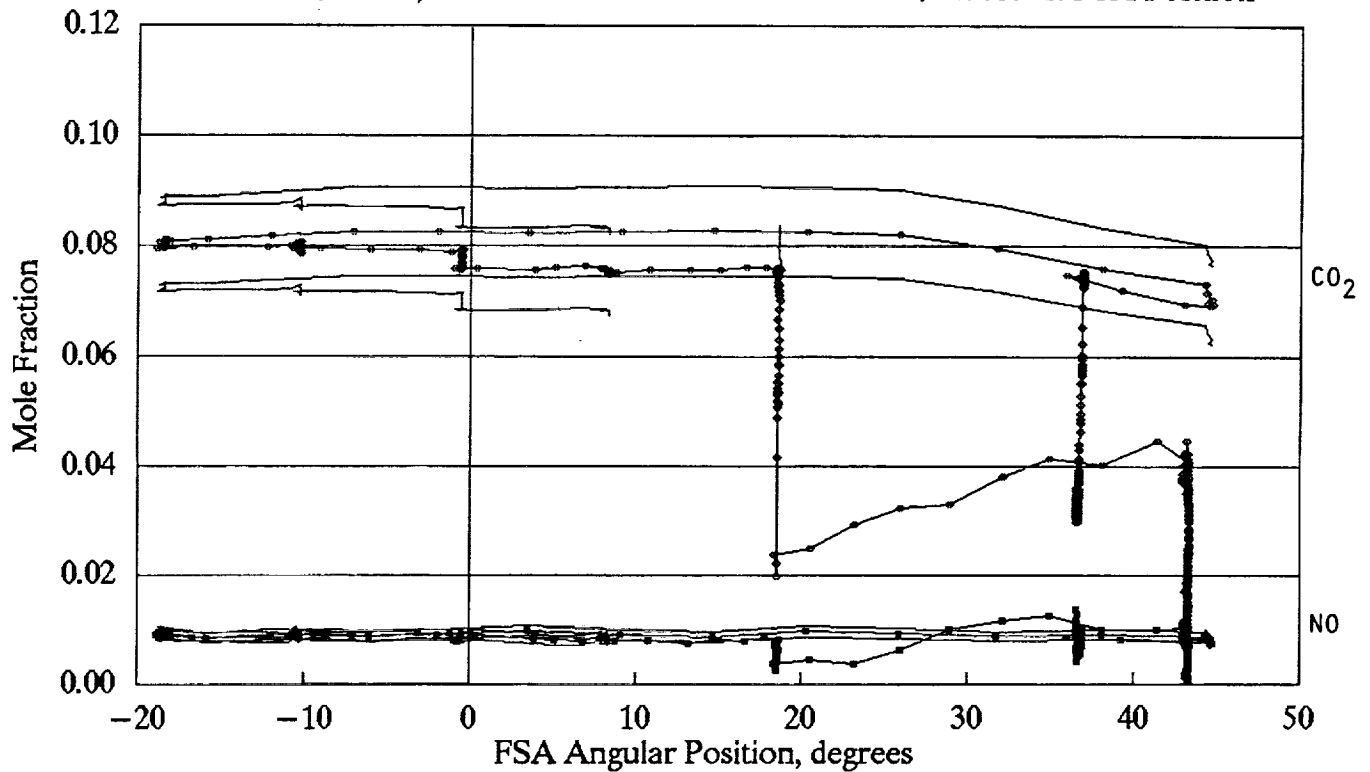
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.075	+/-	0.007
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

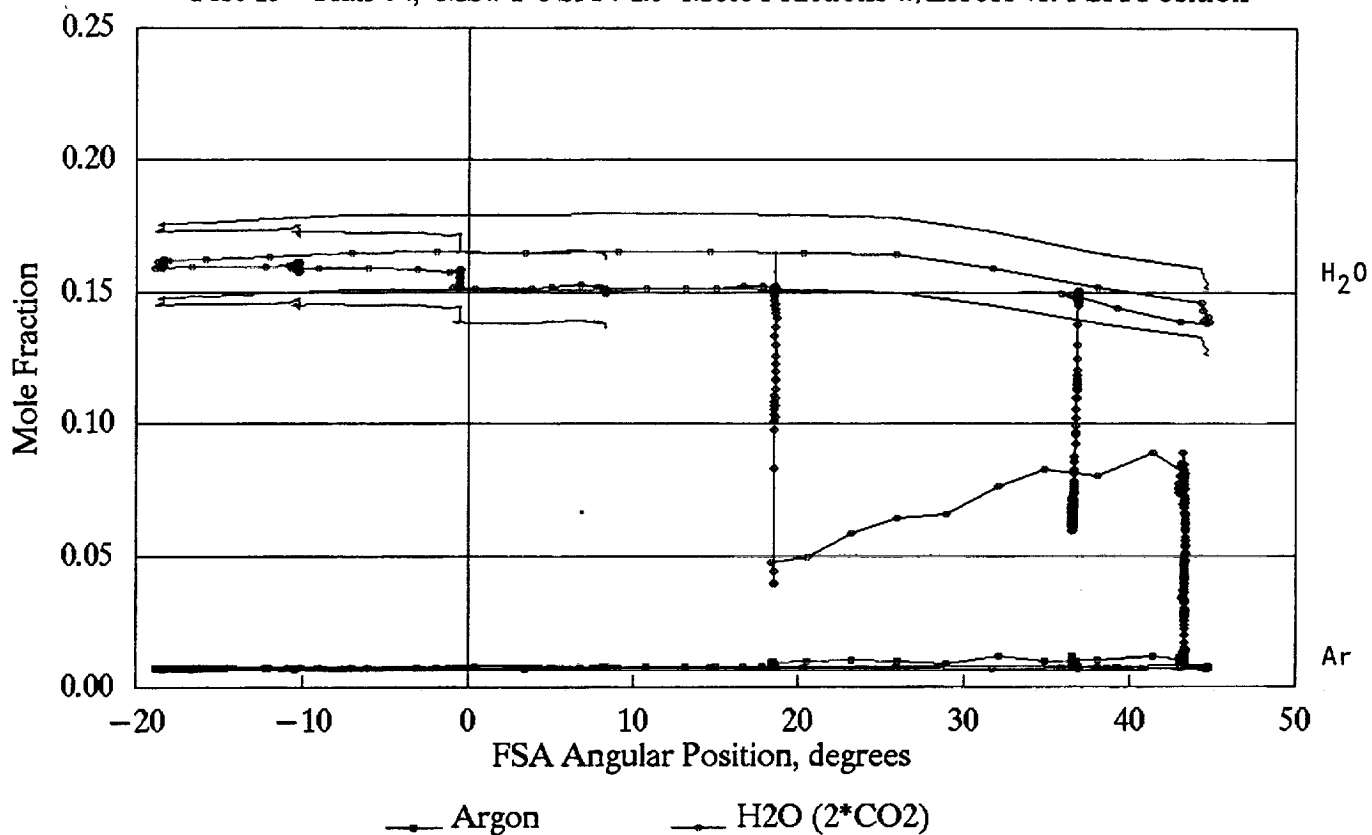
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.079	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 04, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

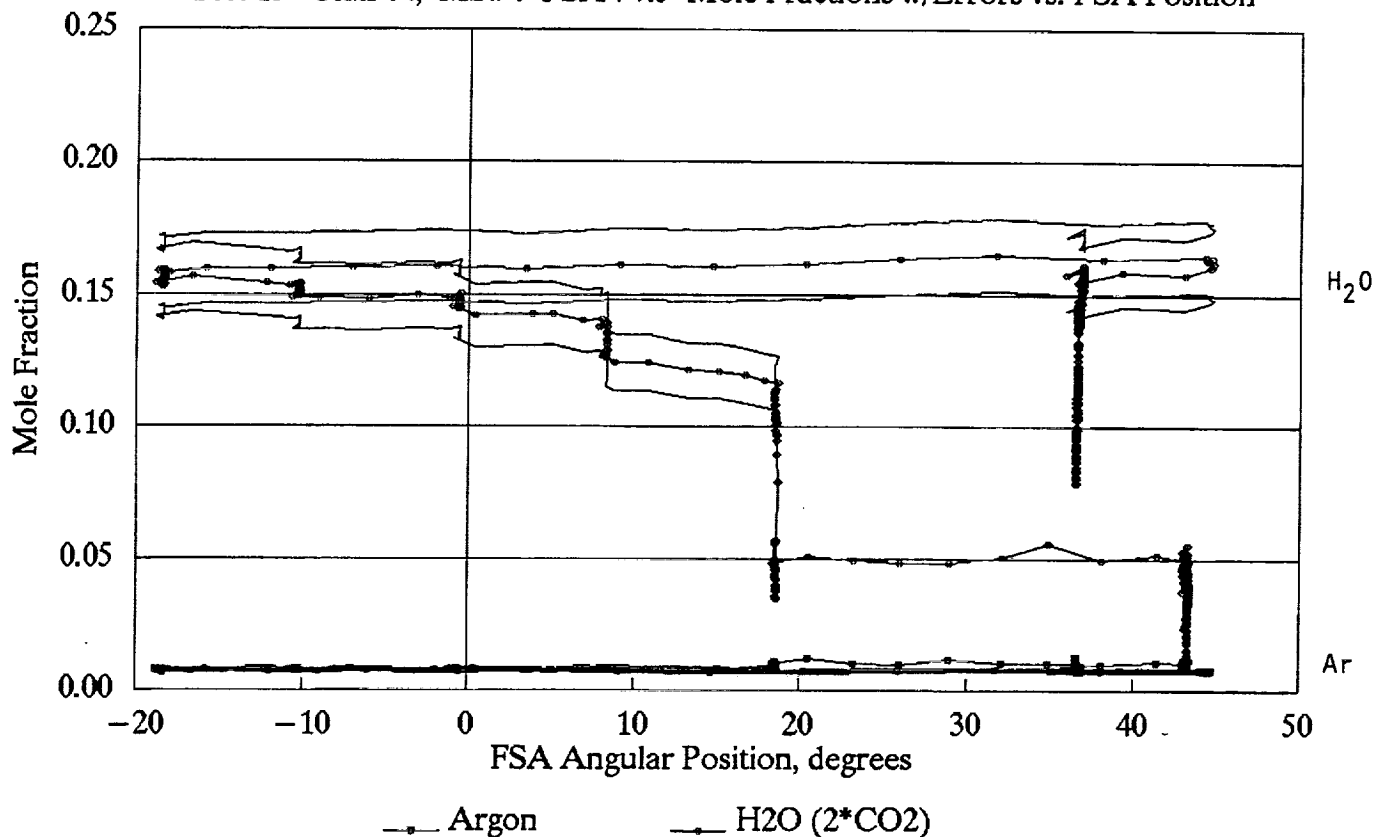
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.157	+/-	0.014

8' HTT Gas Analysis System

Test 139 Run 04, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.150	+/-	0.012

Test 139 Run 5

Combustor Pressure: 2000 psia

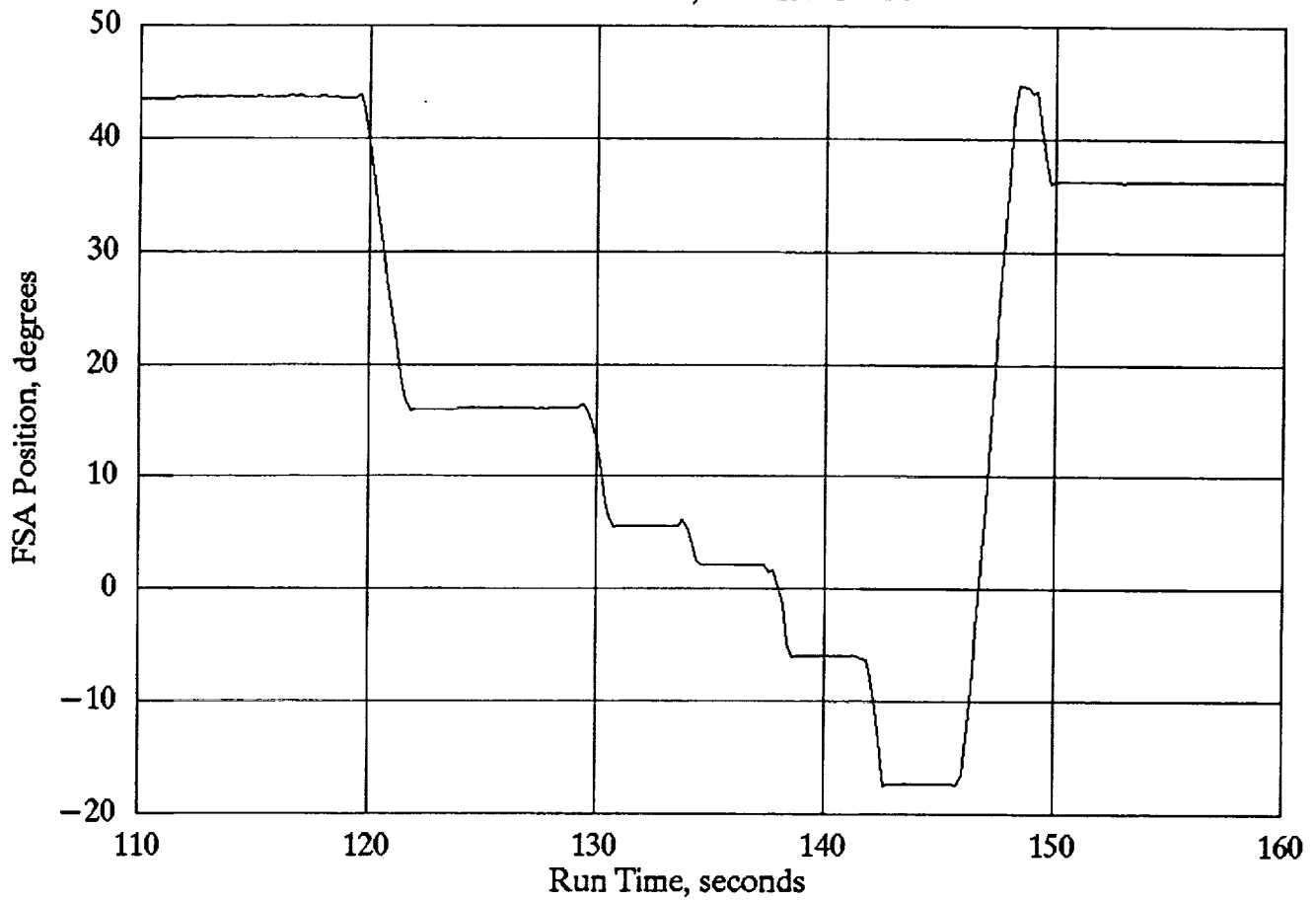
Combustor Temperature: 3300 R

Normal Stop: 149.3 seconds

Probes: FSA+7.5, FSA+1.5

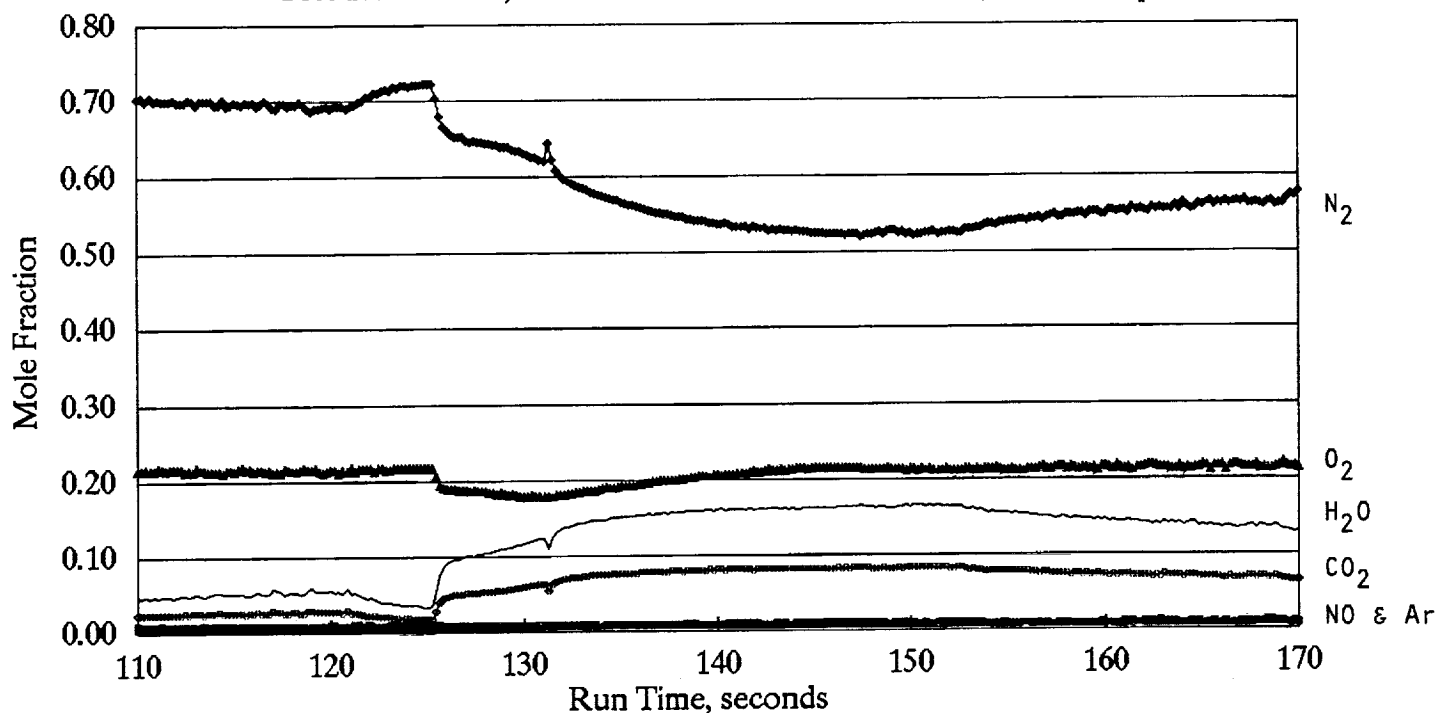
8' HTT Gas Analysis System

FSA Position, Test 139 Run 5



8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

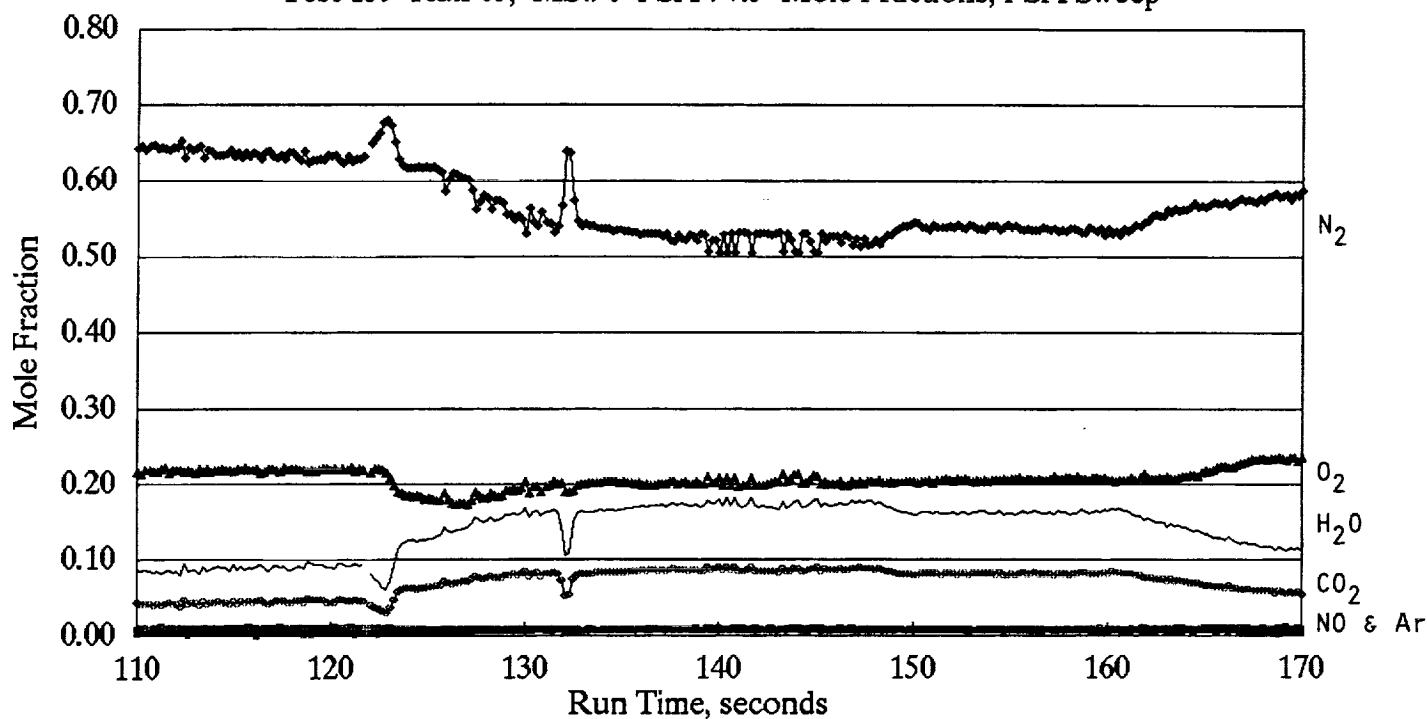
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.528	+/-	0.024
Oxygen:	0.212	+/-	0.018
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.006
H2O:	0.162	+/-	0.012
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions, FSA Sweep



Sum of mole fractions = 1.

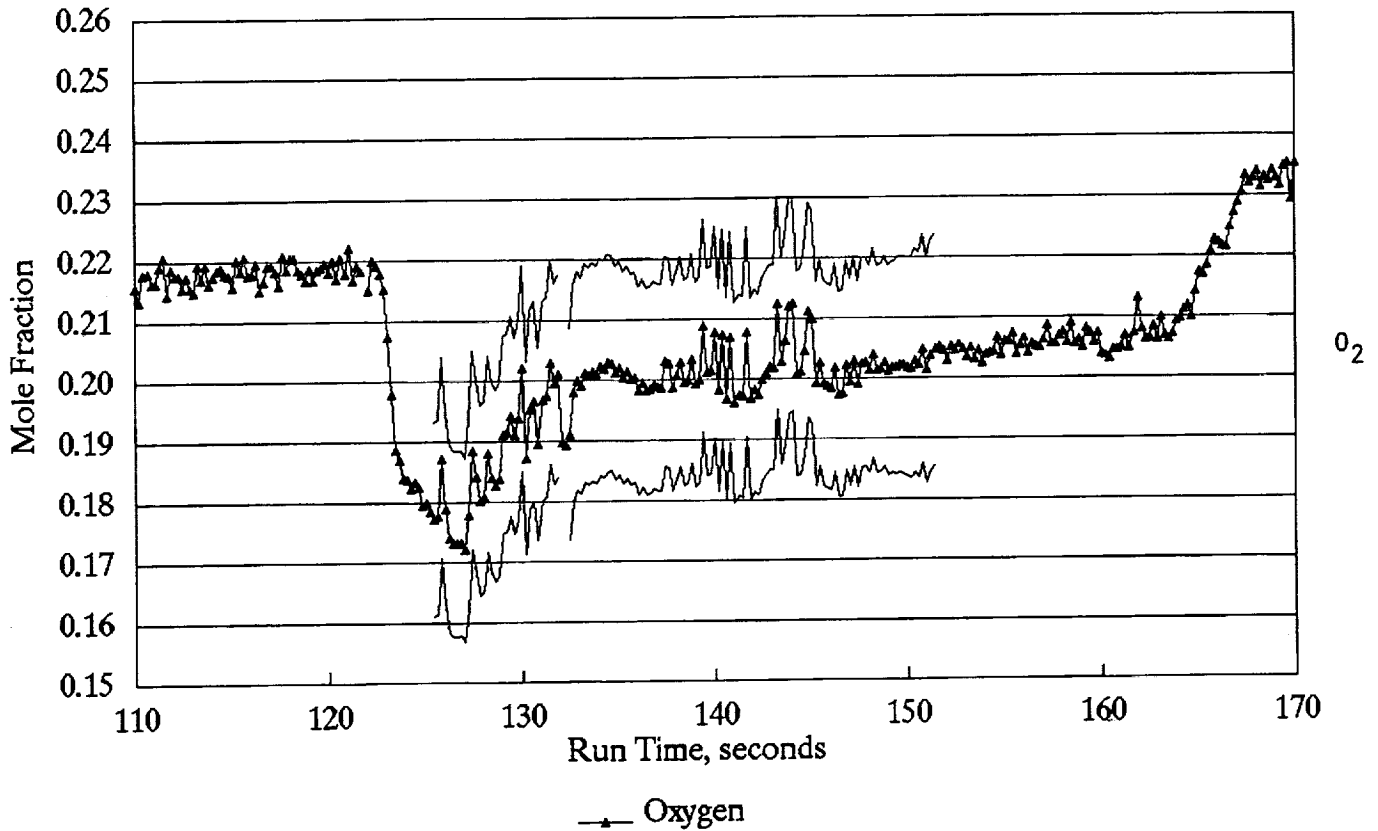
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.524	+/-	0.025
Oxygen:	0.202	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.086	+/-	0.013
H2O:	0.172	+/-	0.025
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

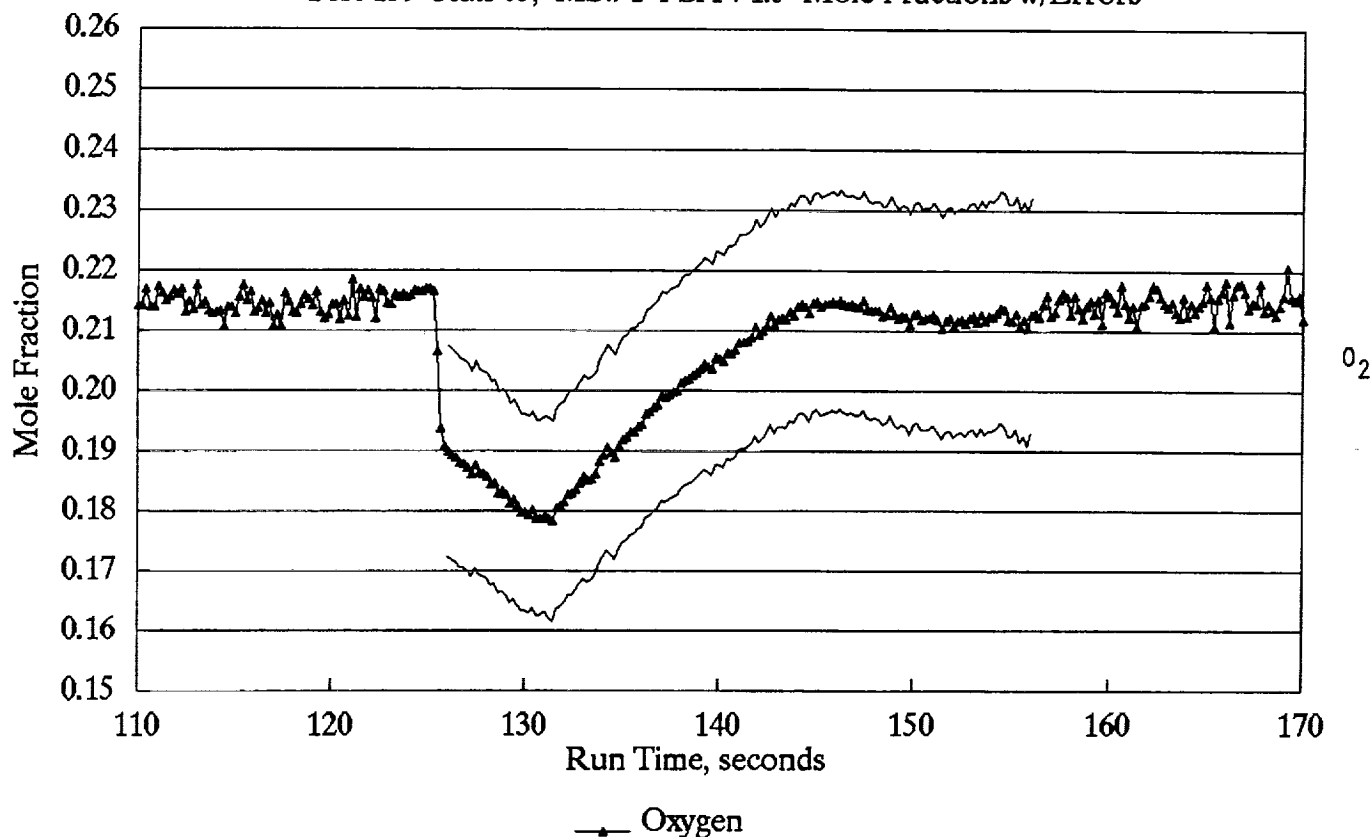
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.202 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

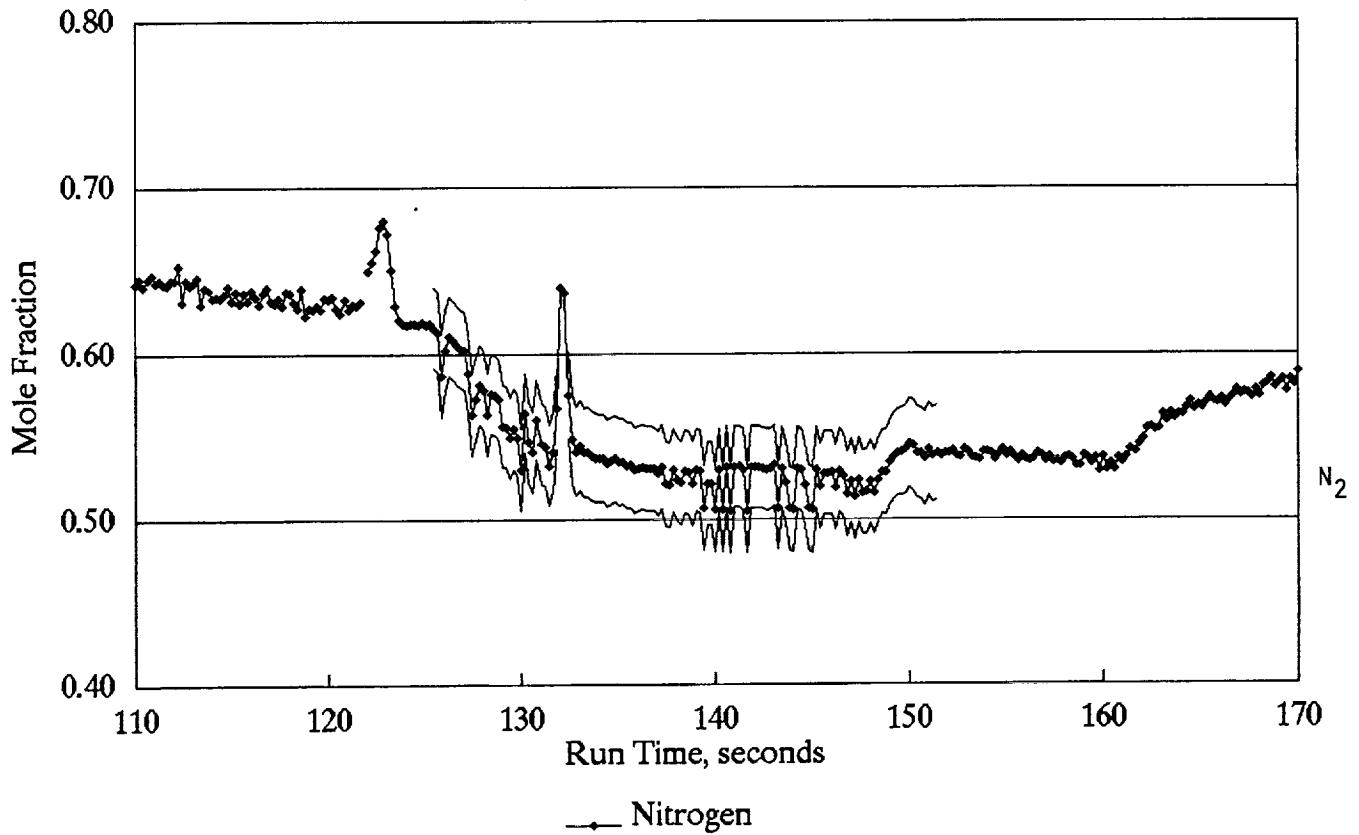
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.212 +/- 0.018

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

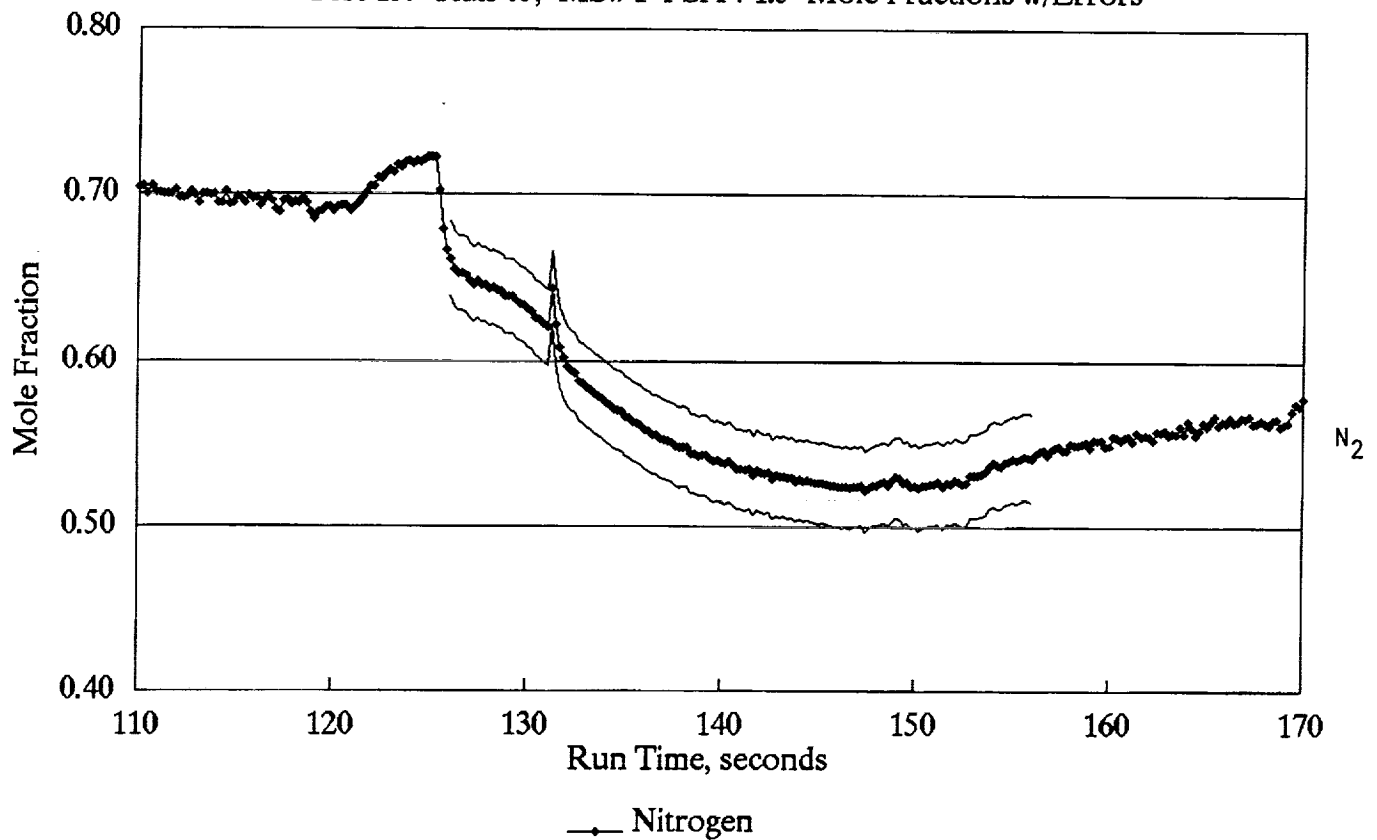
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.524 +/- 0.025

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

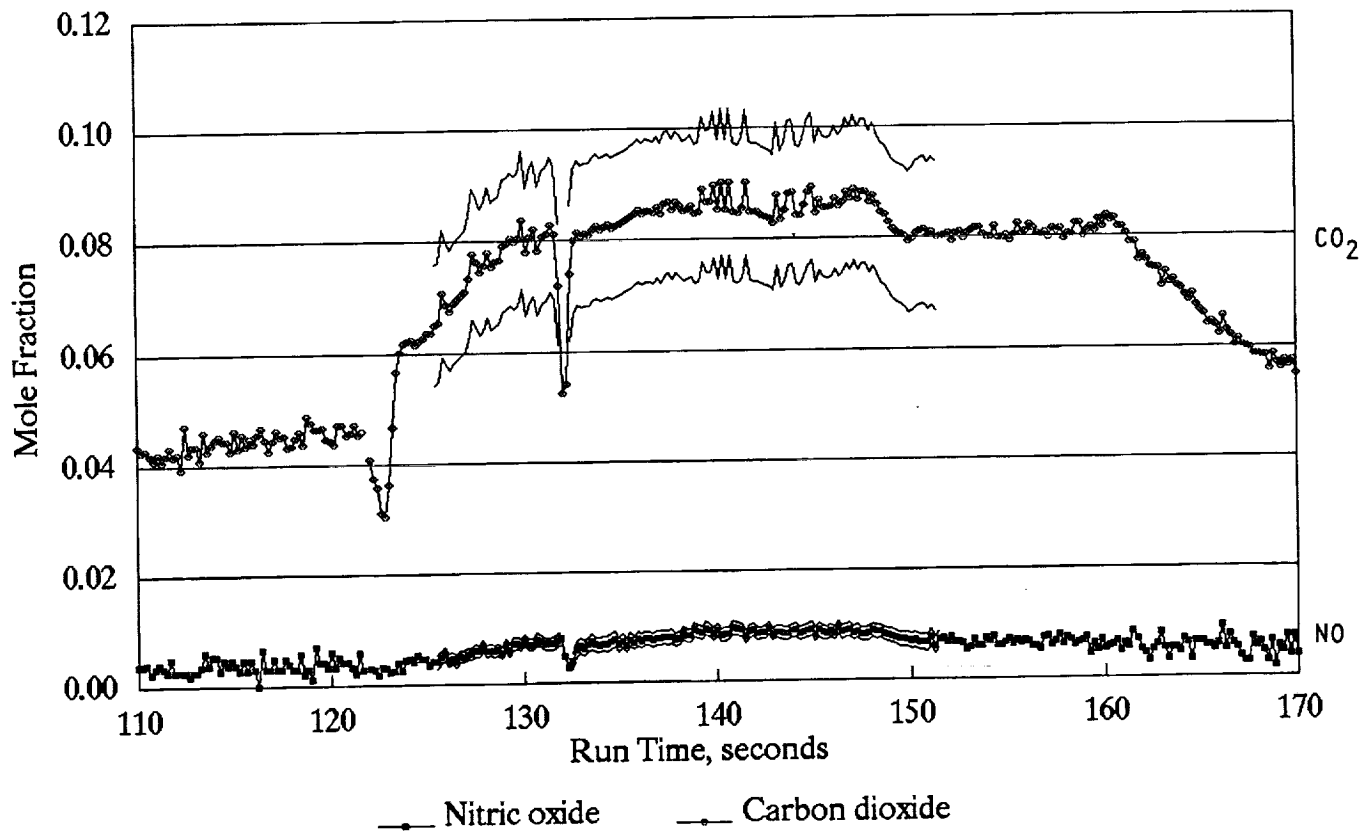
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.528 +/- 0.024

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

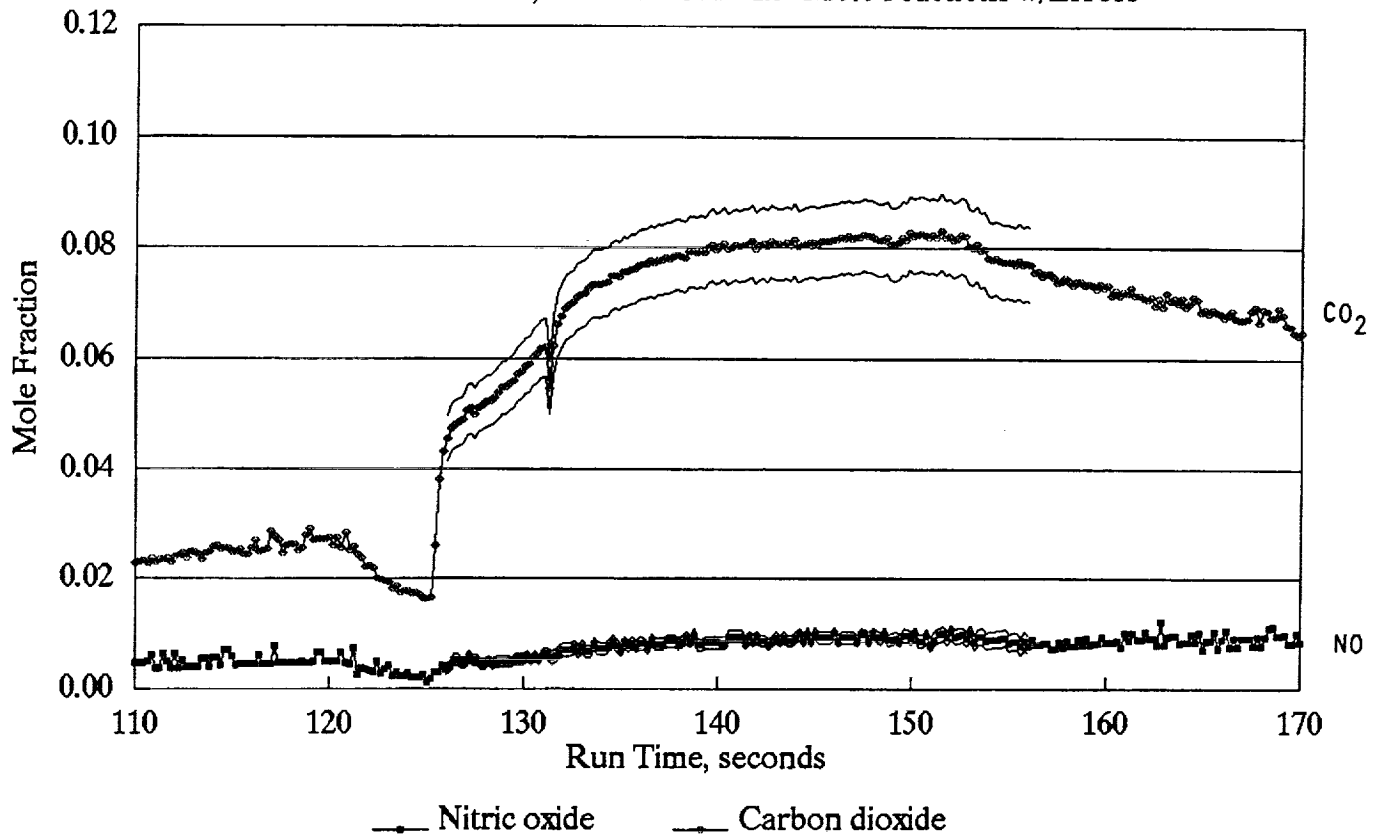
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.086	+/-	0.013
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

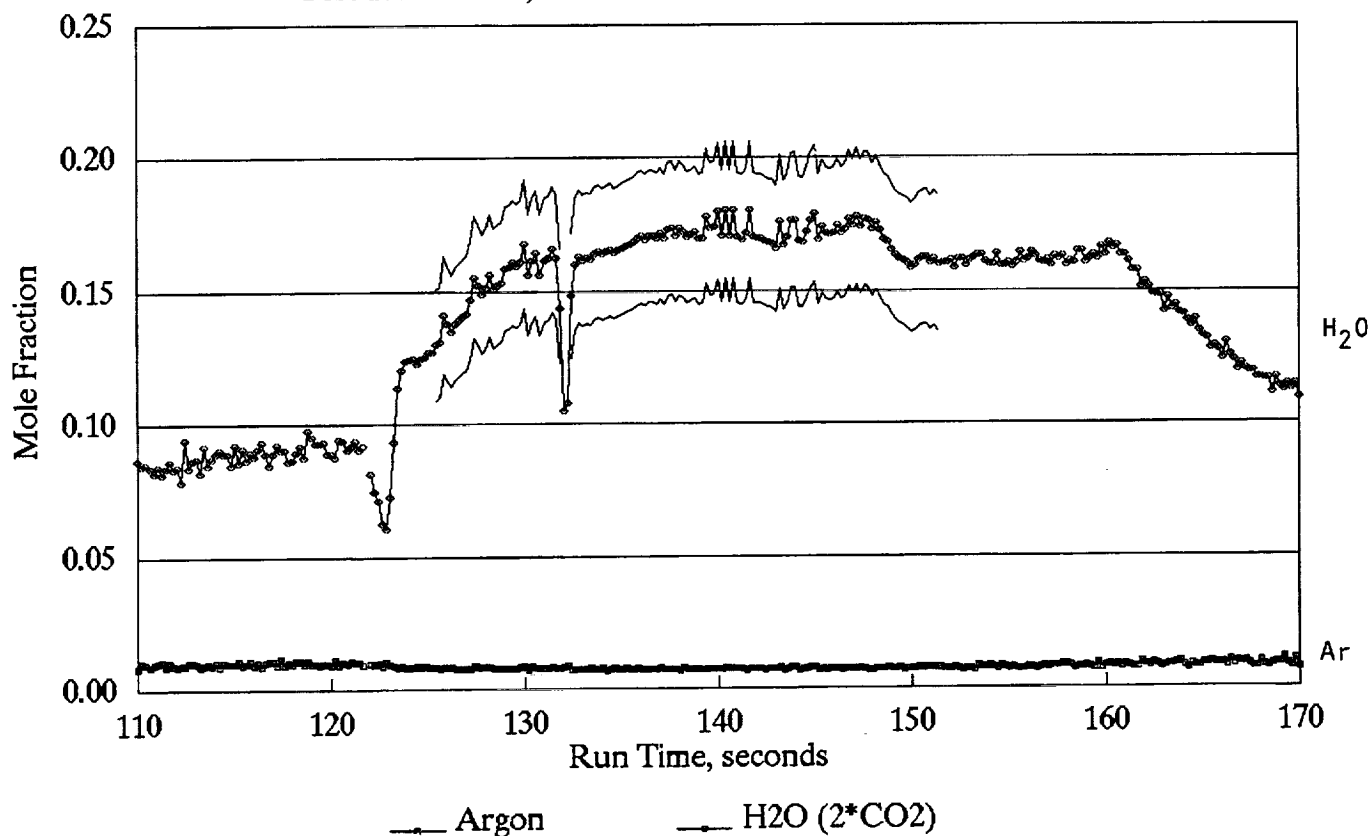
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.081	+/-	0.006
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

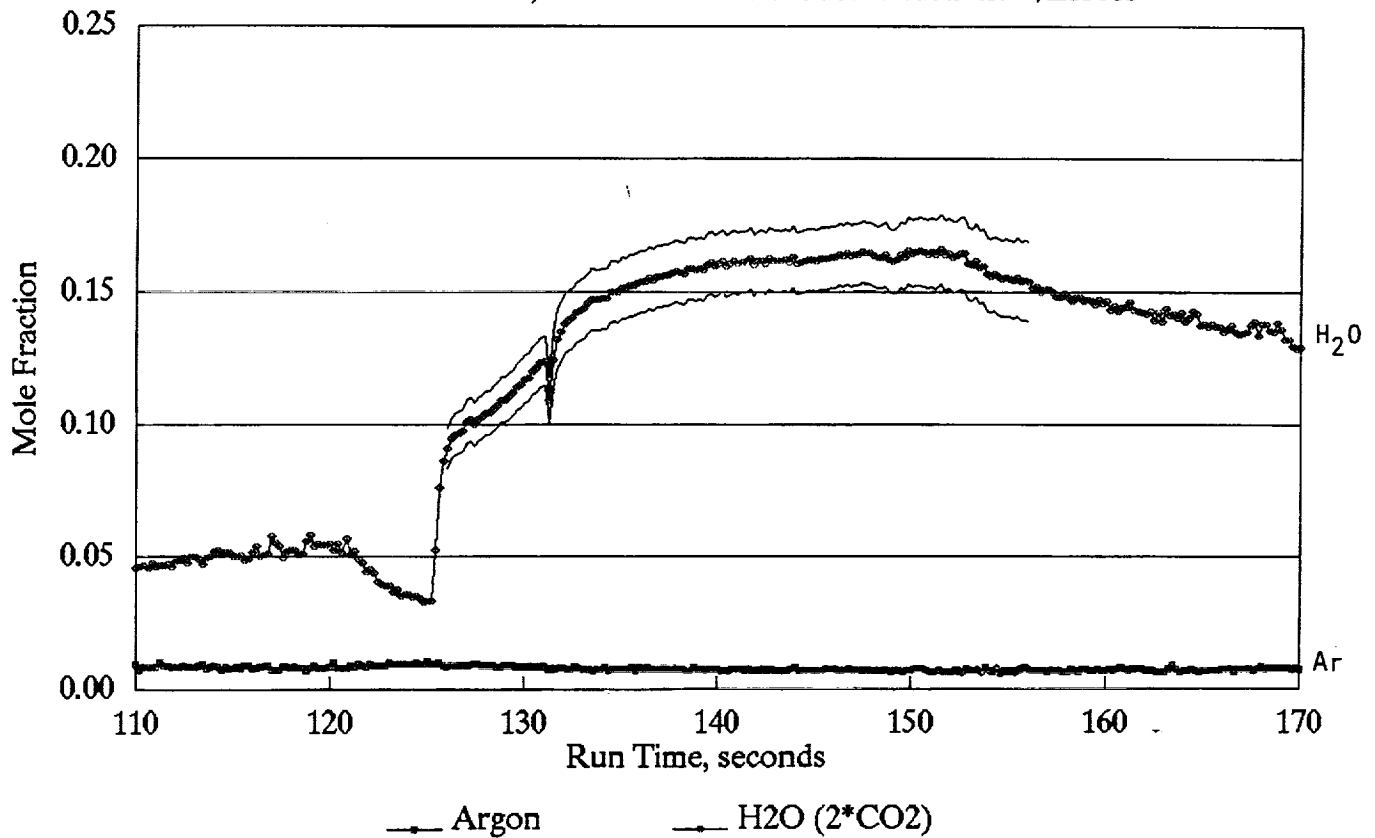
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.172	+/-	0.025

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

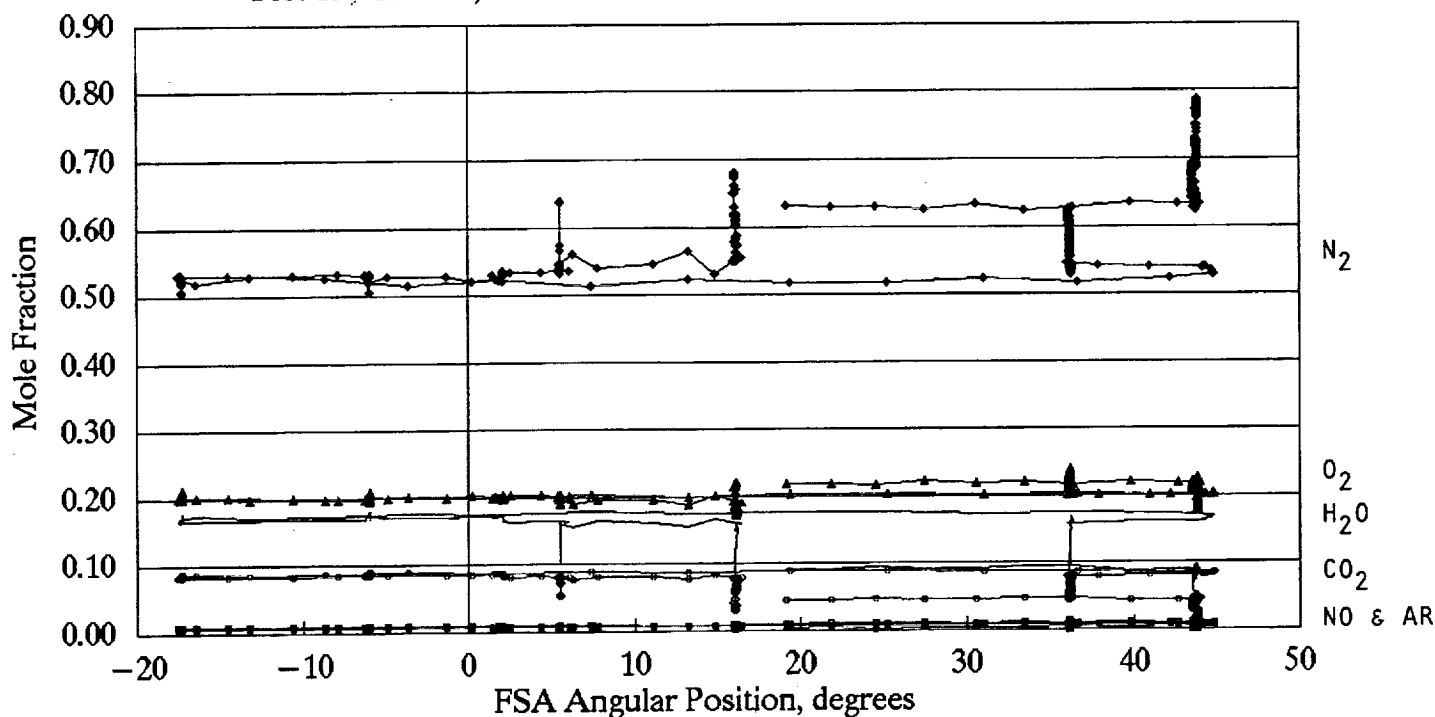
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.012

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

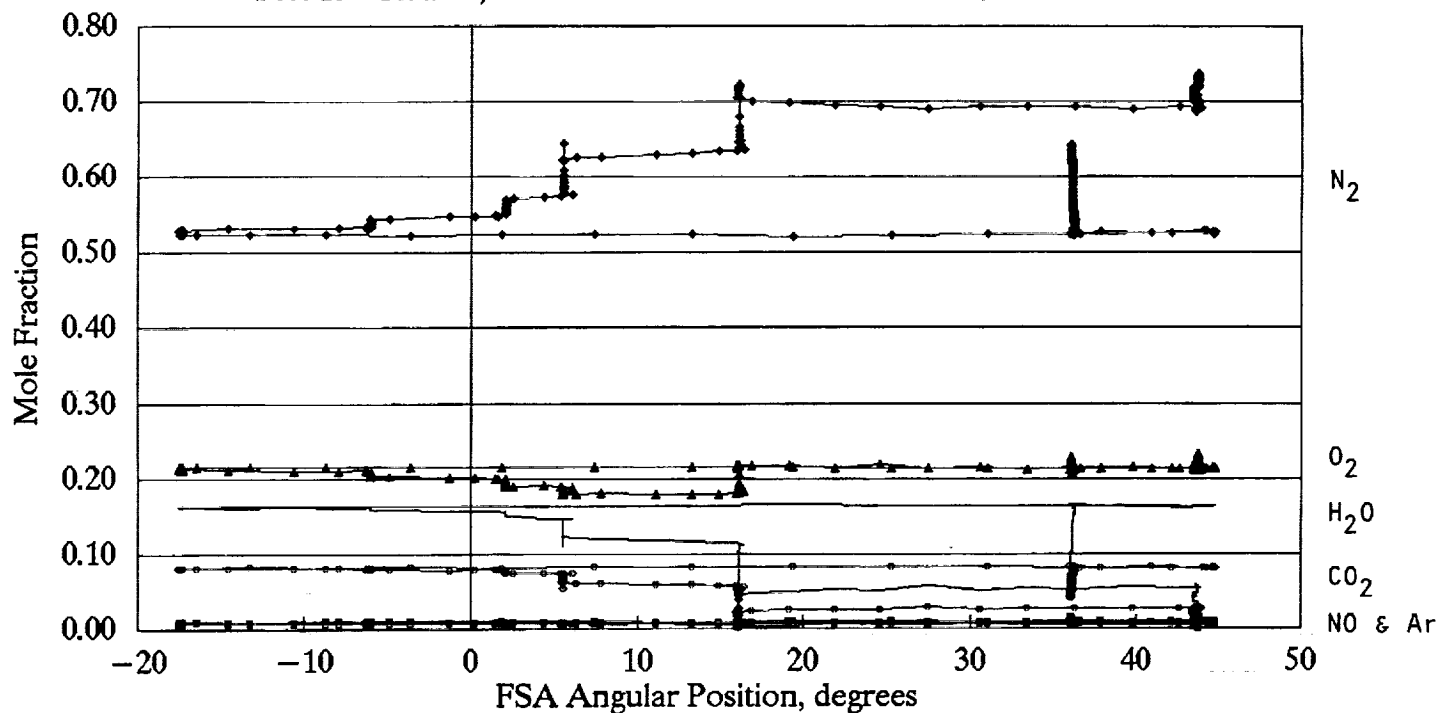
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.524	+/-	0.025
Oxygen:	0.202	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.086	+/-	0.013
H2O:	0.172	+/-	0.025
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13 9 Run 05, MS#1 FSA +1.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

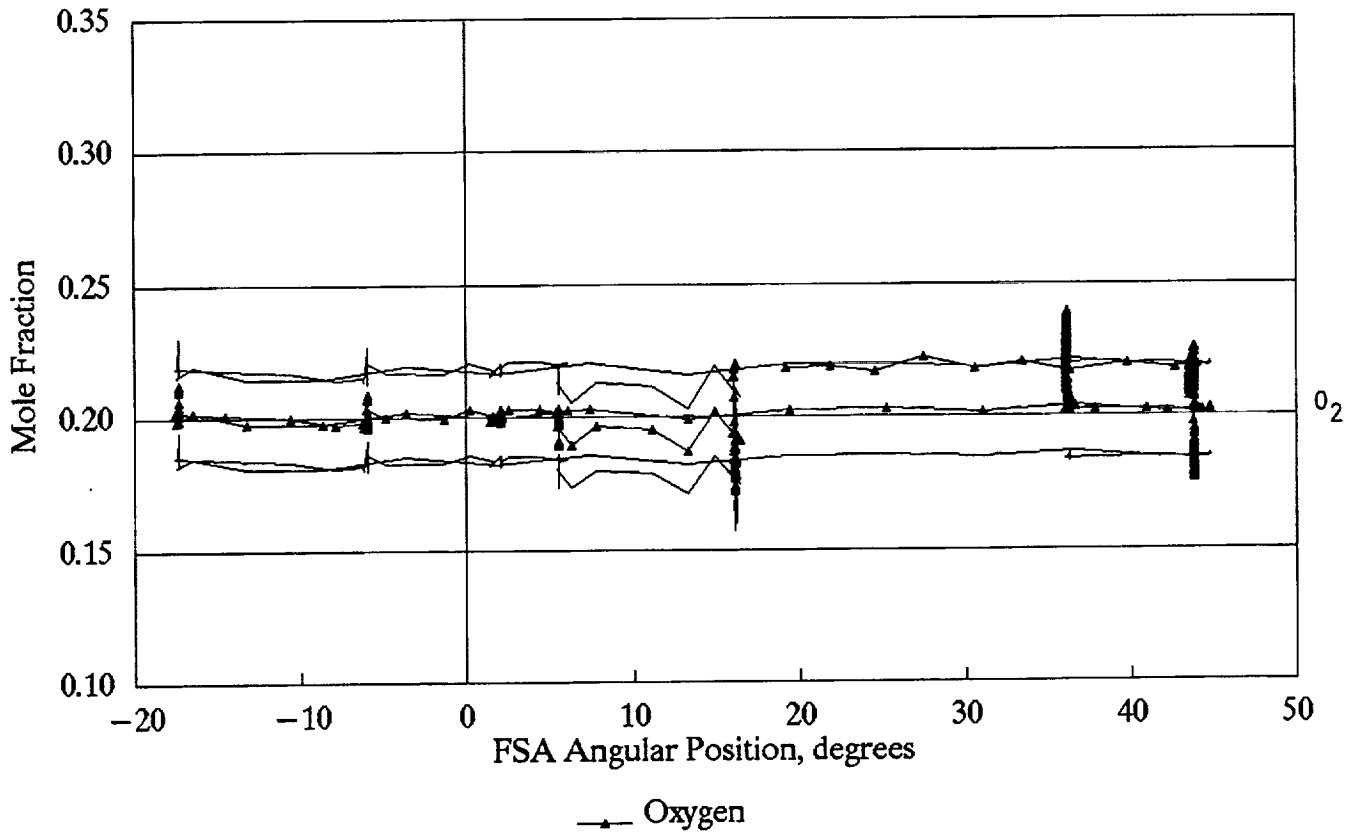
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.528	+/-	0.024
Oxygen:	0.212	+/-	0.018
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.006
H2O:	0.162	+/-	0.012
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

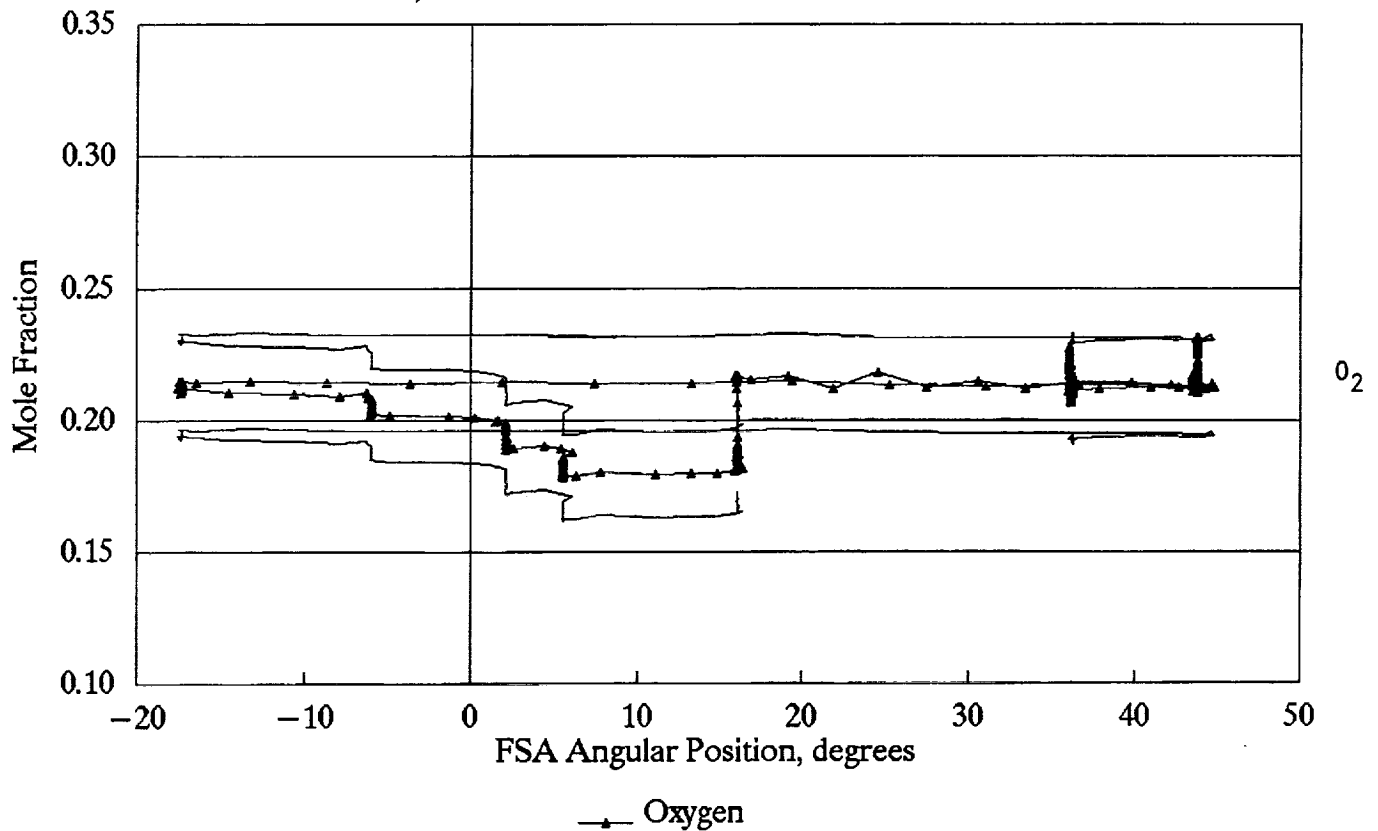
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.202 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

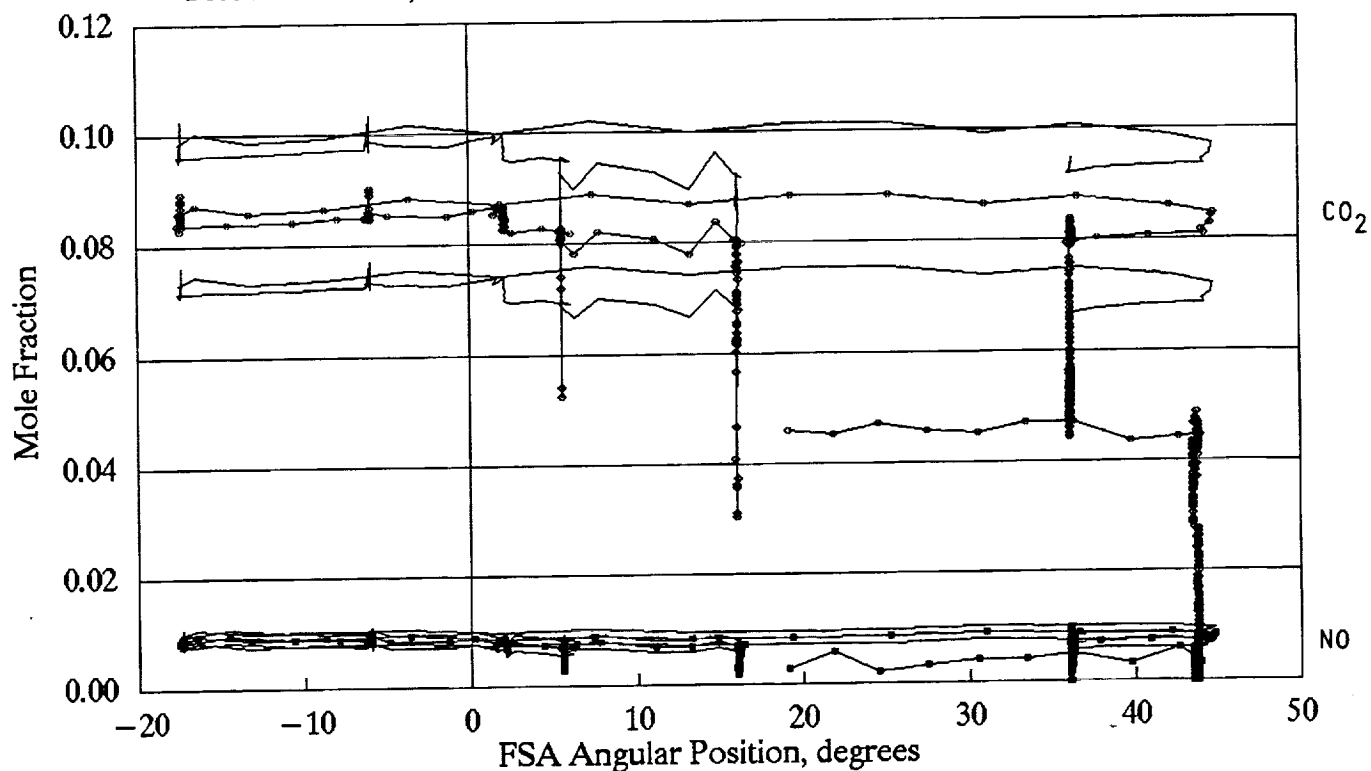
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.212 +/- 0.018

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

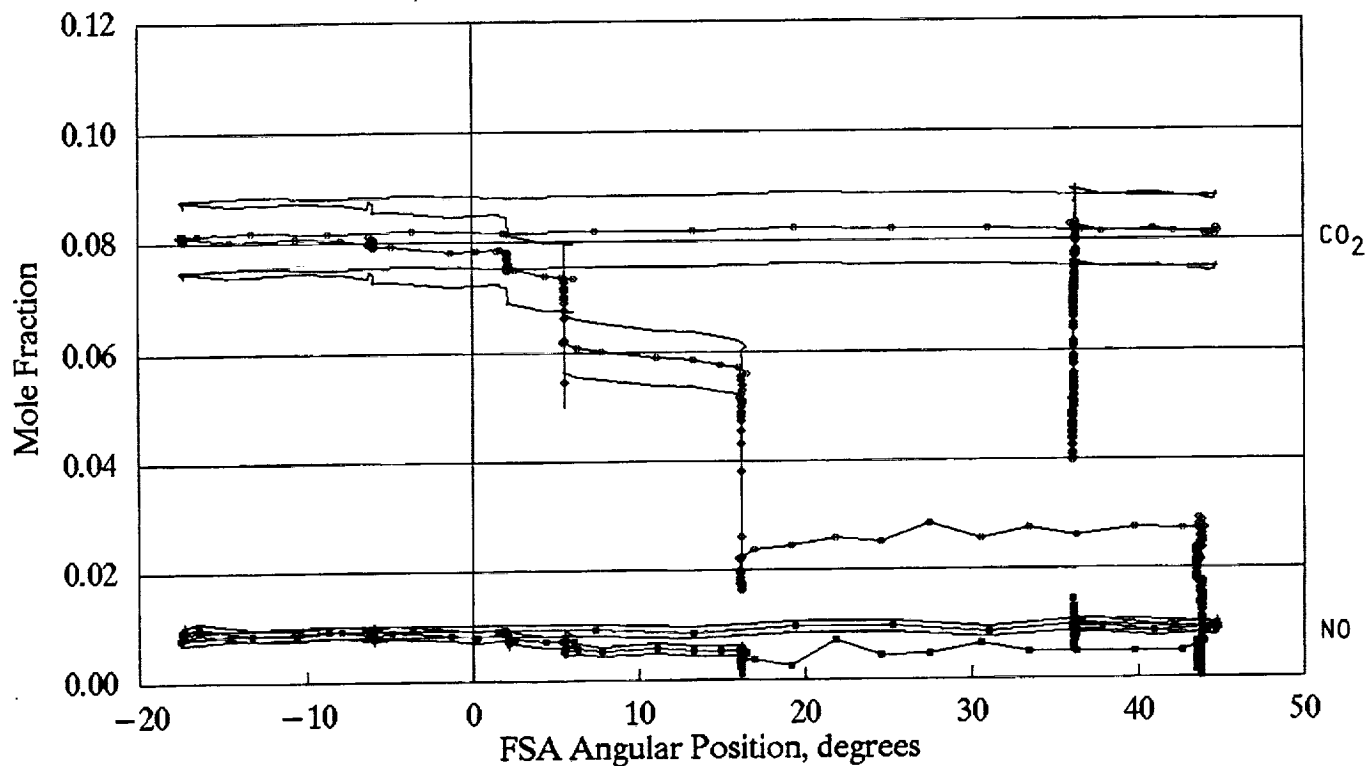
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.086	+/-	0.013
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

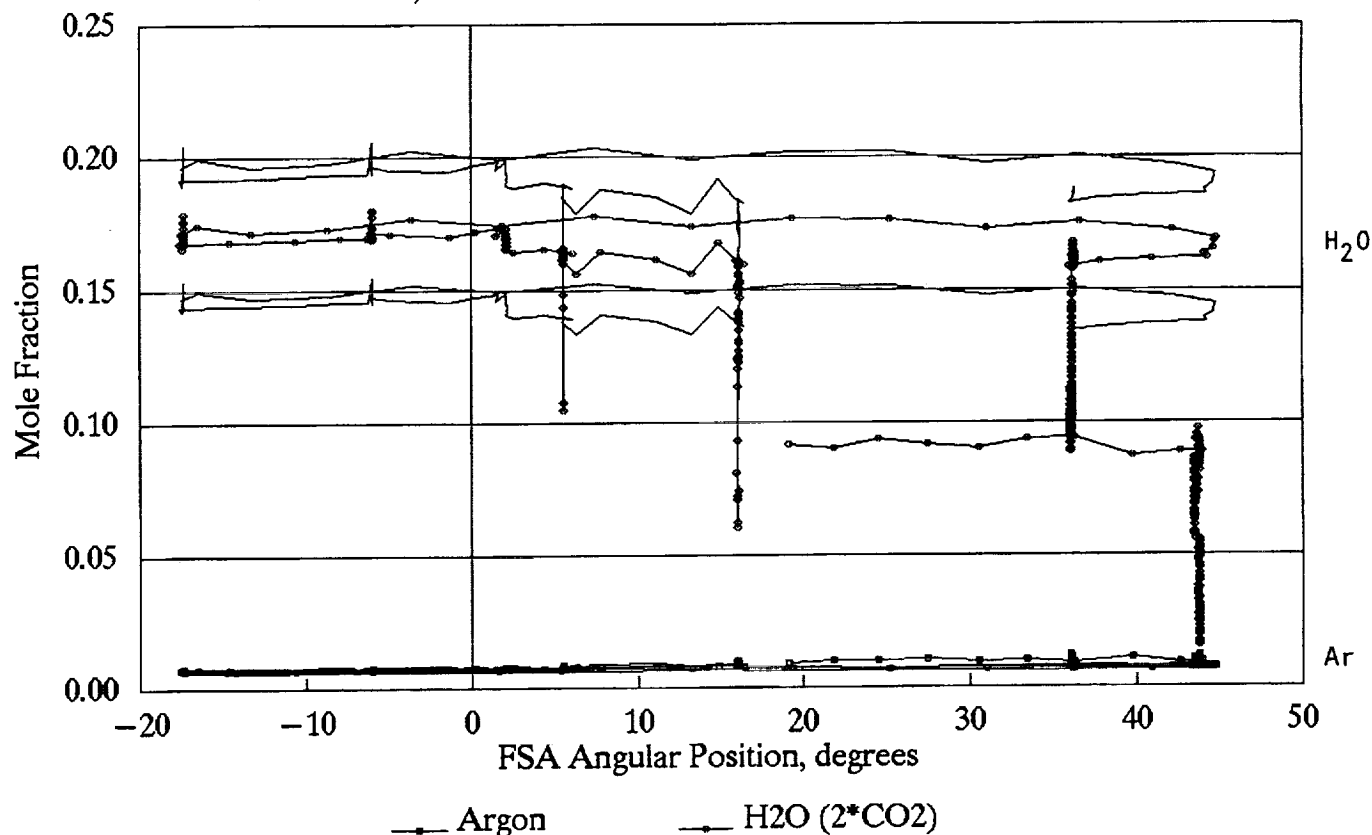
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.081	+/-	0.006
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 05, MS#0 FSA +7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

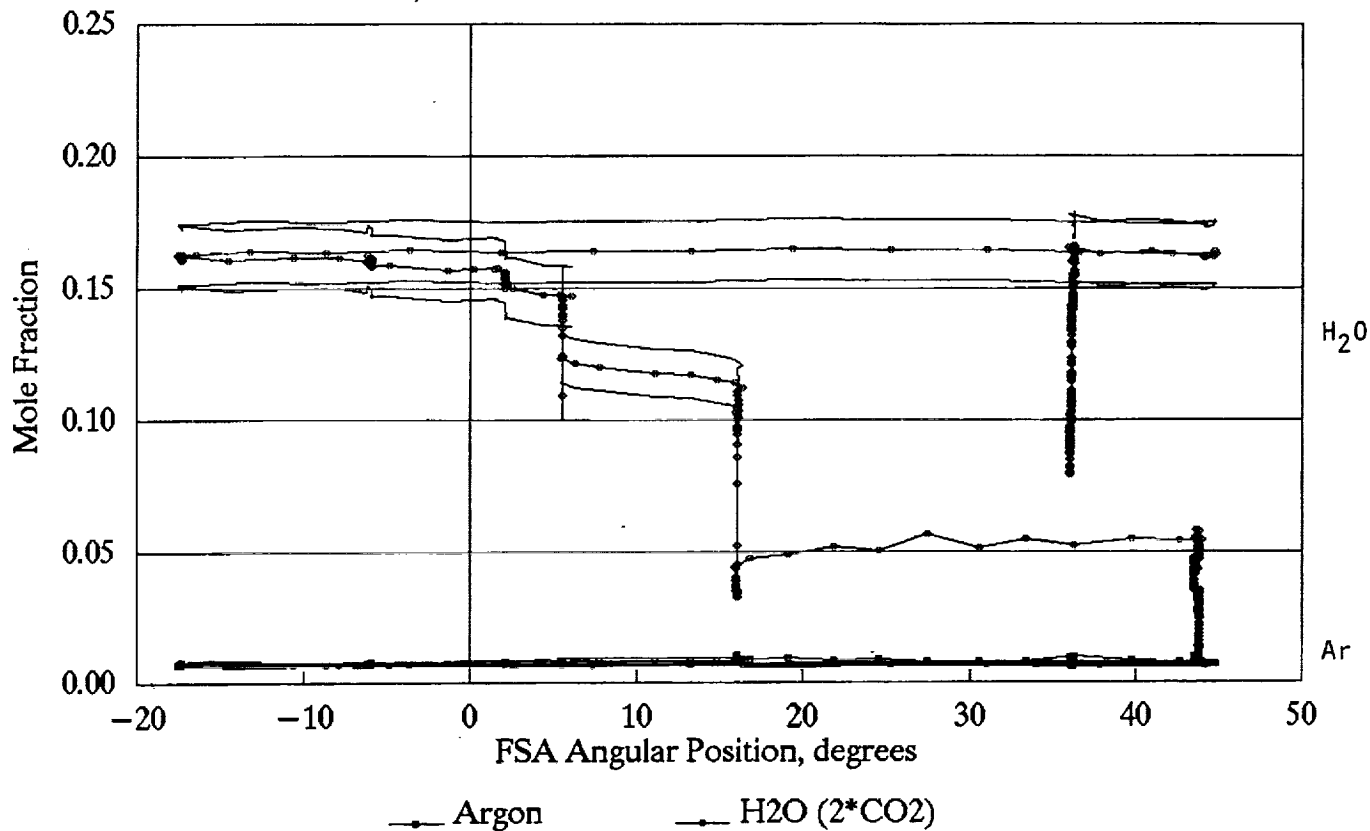
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.172	+/-	0.025

8' HTT Gas Analysis System

Test 139 Run 05, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.012

Test 139 Run 6

Combustor Pressure: 2000 psia

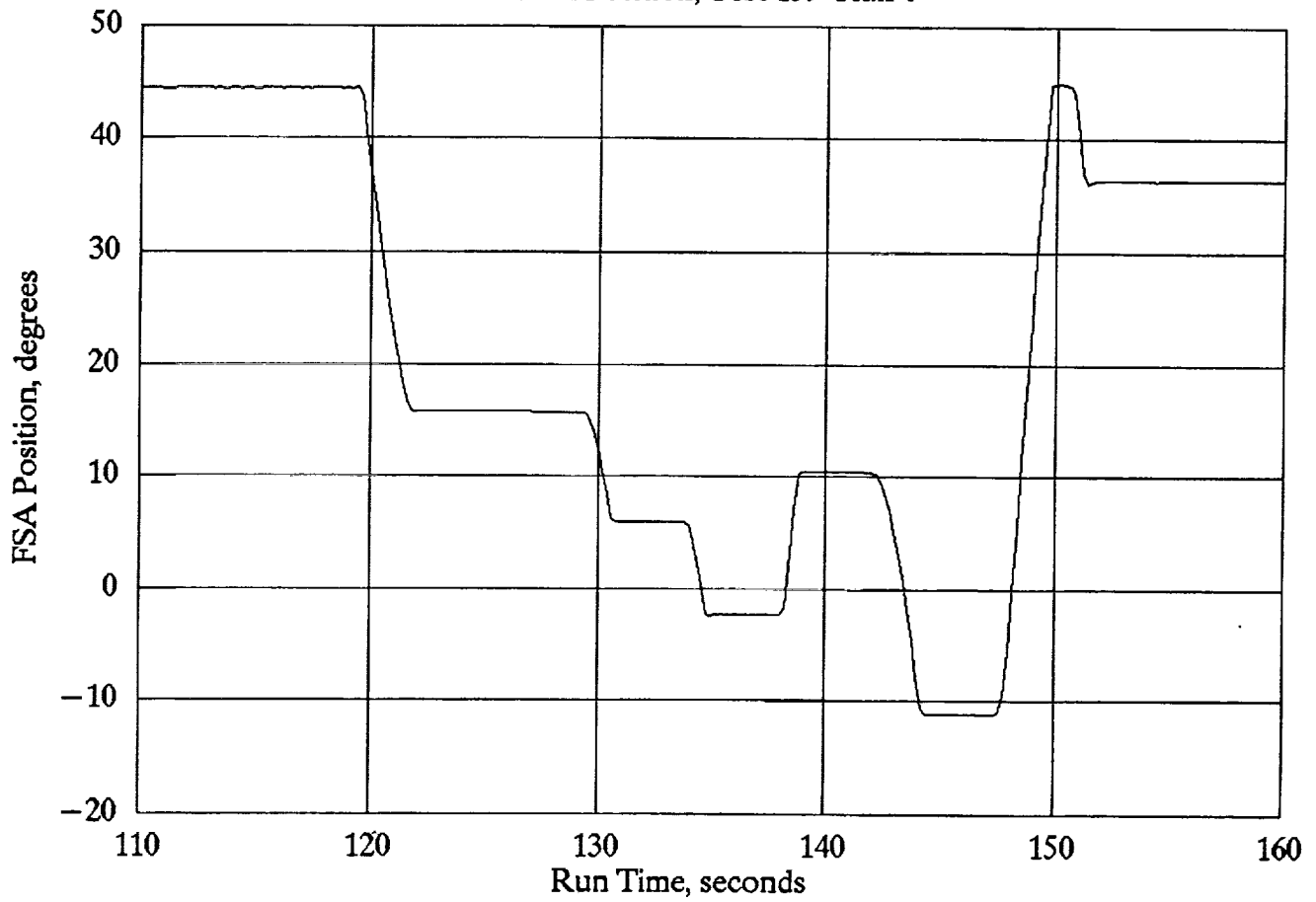
Combustor Temperature: 3300 R

Normal Stop: 151.7 seconds

Probes: FSA+7.5, FSA+1.5, FSA-1.5

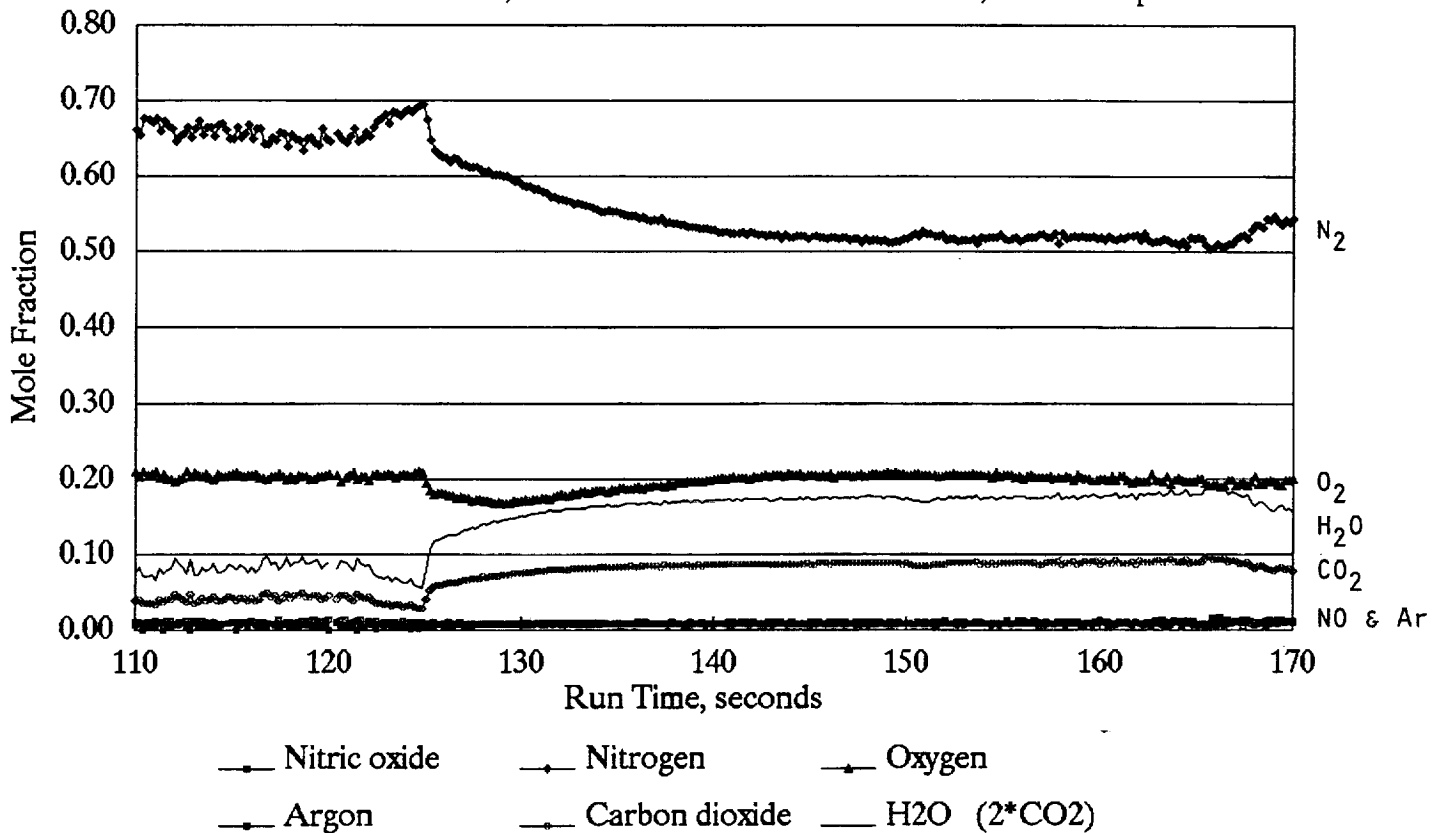
8' HTT Gas Analysis System

FSA Position, Test 139 Run 6



8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions, FSA Sweep



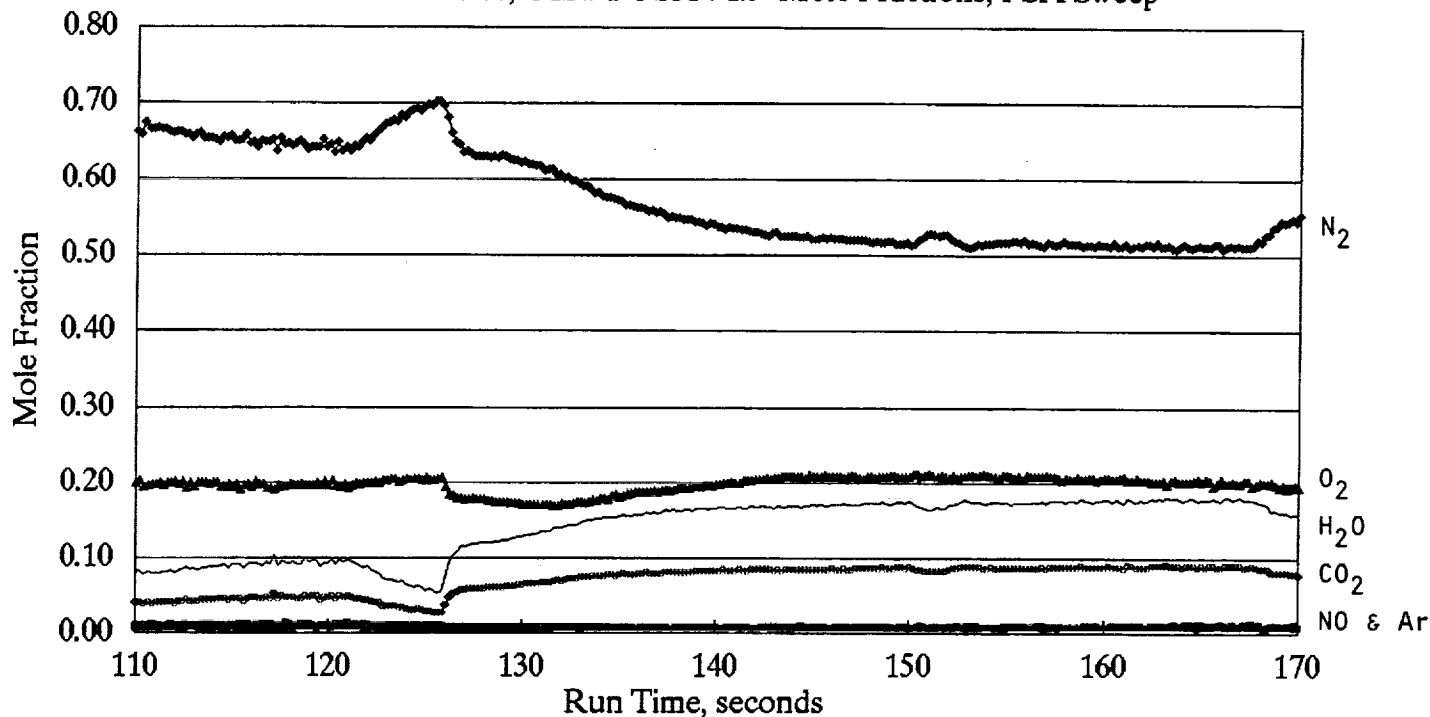
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.520	+/-	0.033
Oxygen:	0.204	+/-	0.022
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.087	+/-	0.017
H2O:	0.173	+/-	0.031
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

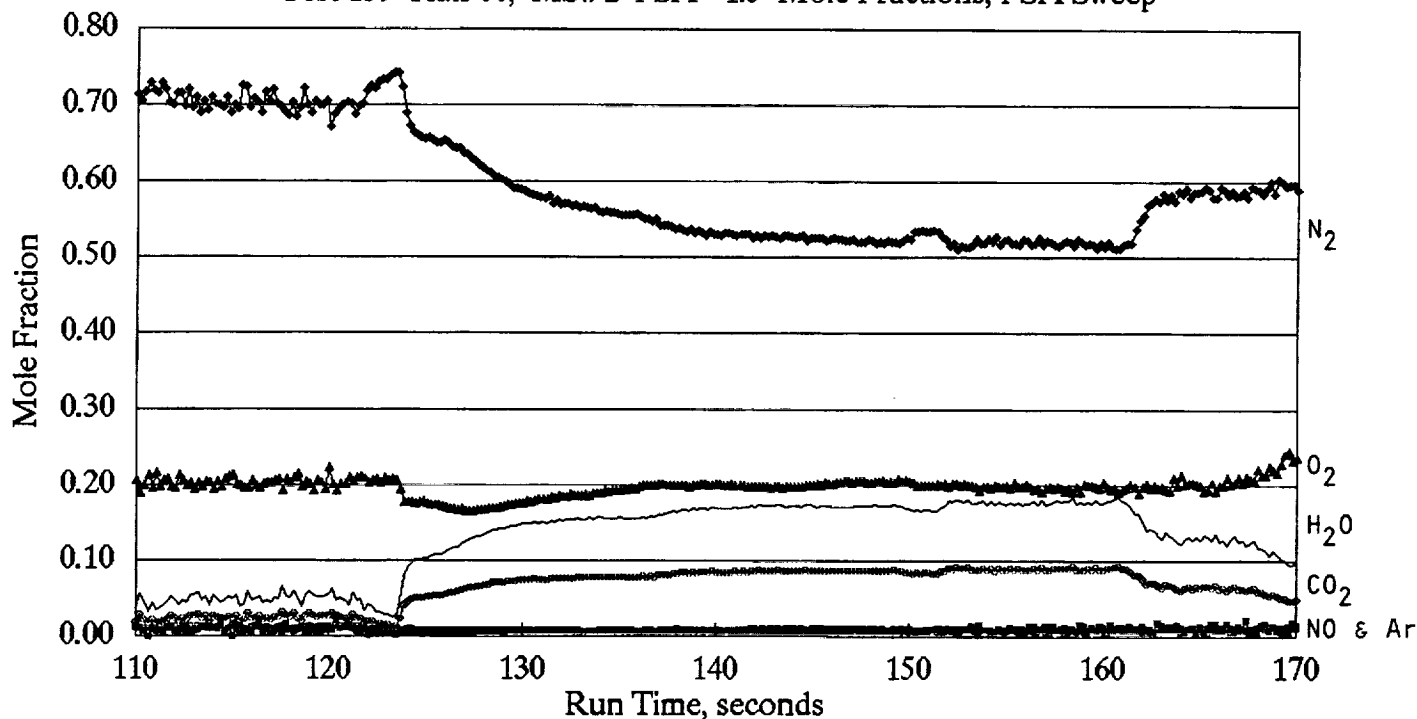
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.525	+/-	0.026
Oxygen:	0.206	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.085	+/-	0.013
H ₂ O:	0.169	+/-	0.025
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

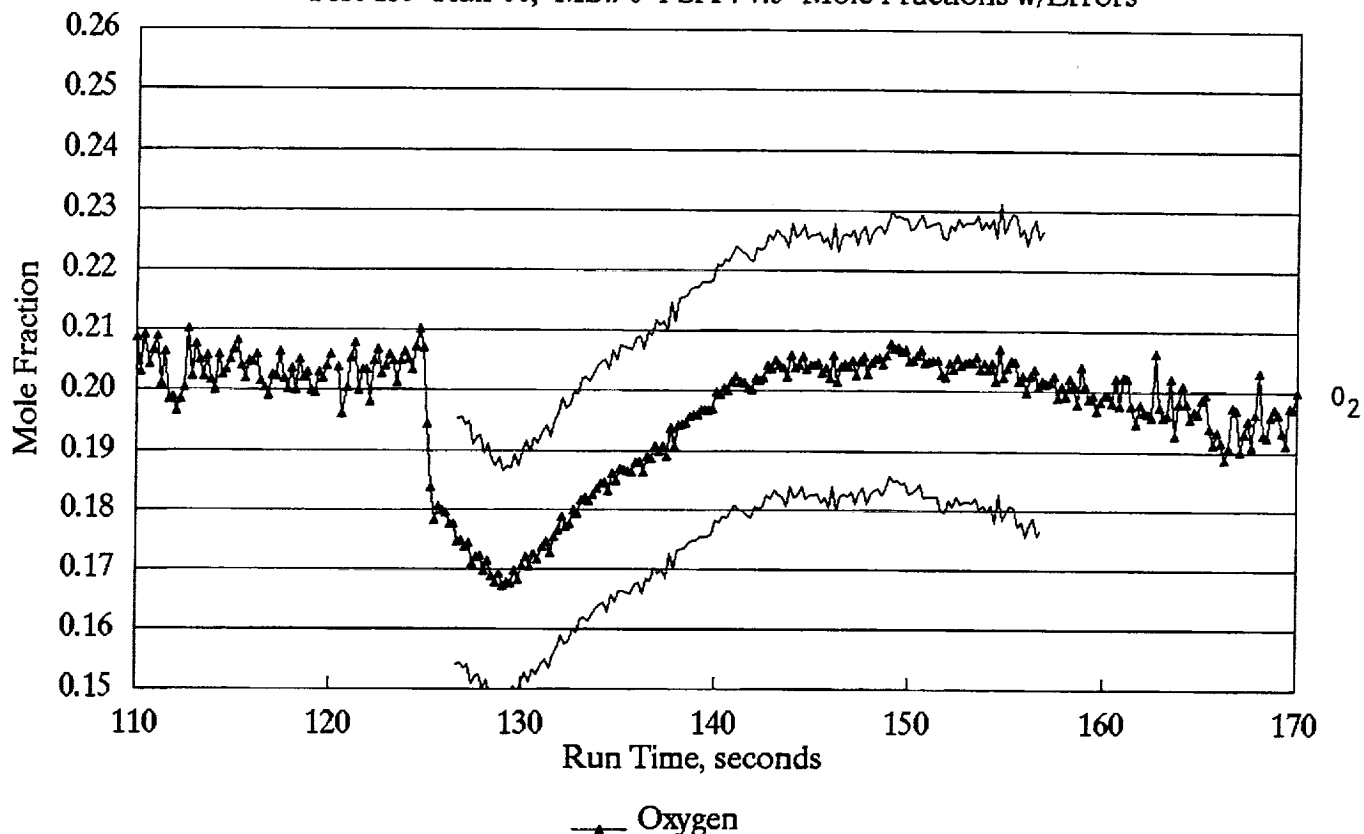
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.526	+/-	0.020
Oxygen:	0.201	+/-	0.013
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.086	+/-	0.011
H2O:	0.172	+/-	0.020
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA +7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

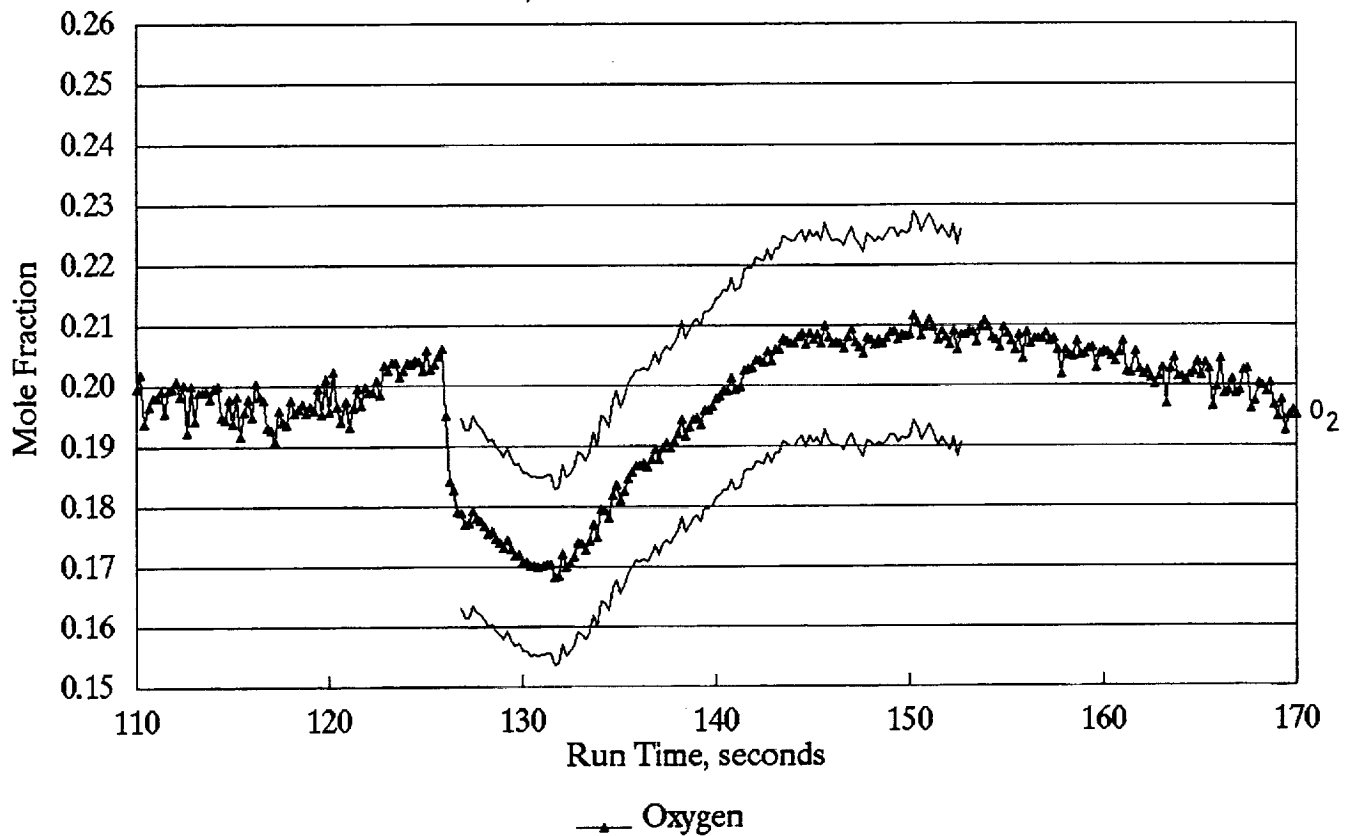
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.204 +/- 0.022

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

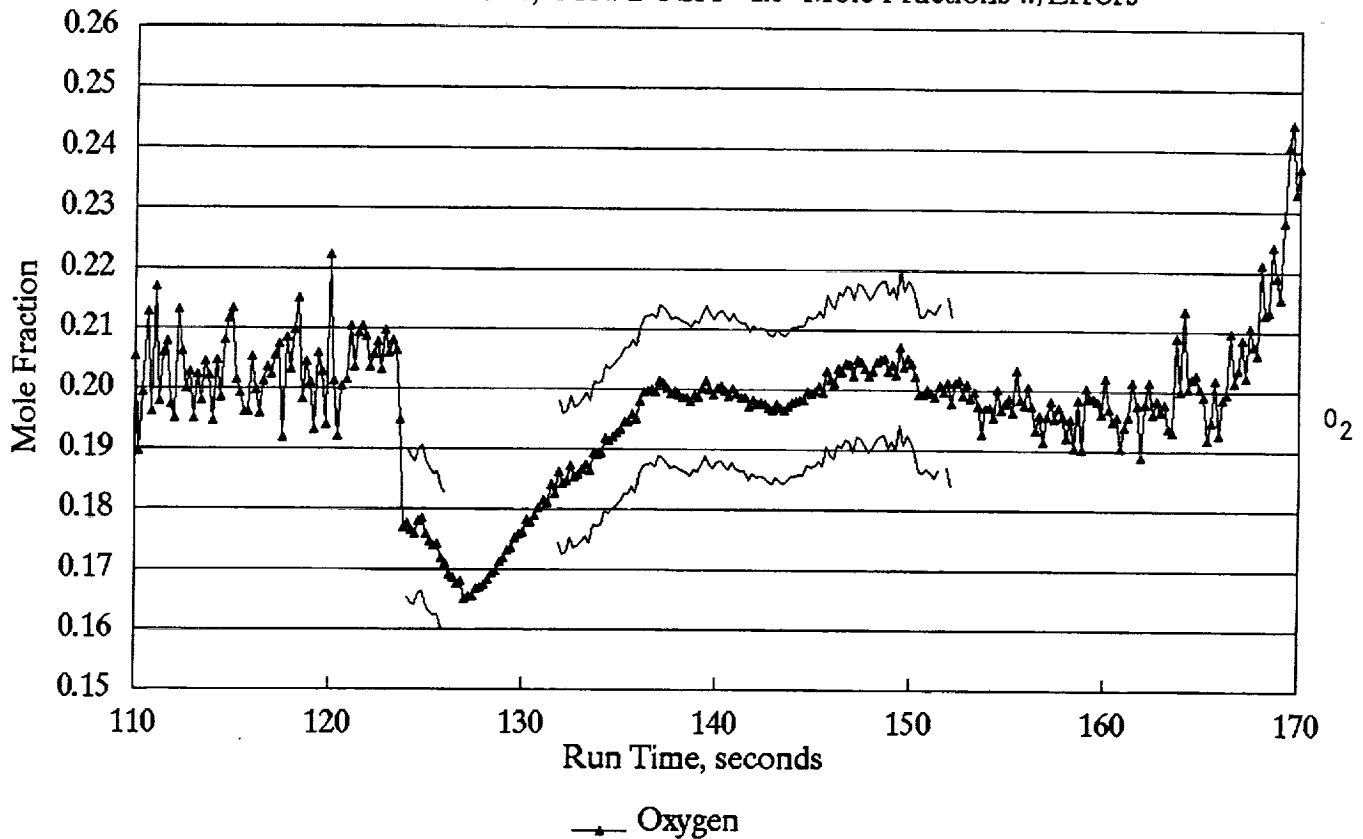
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.206 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

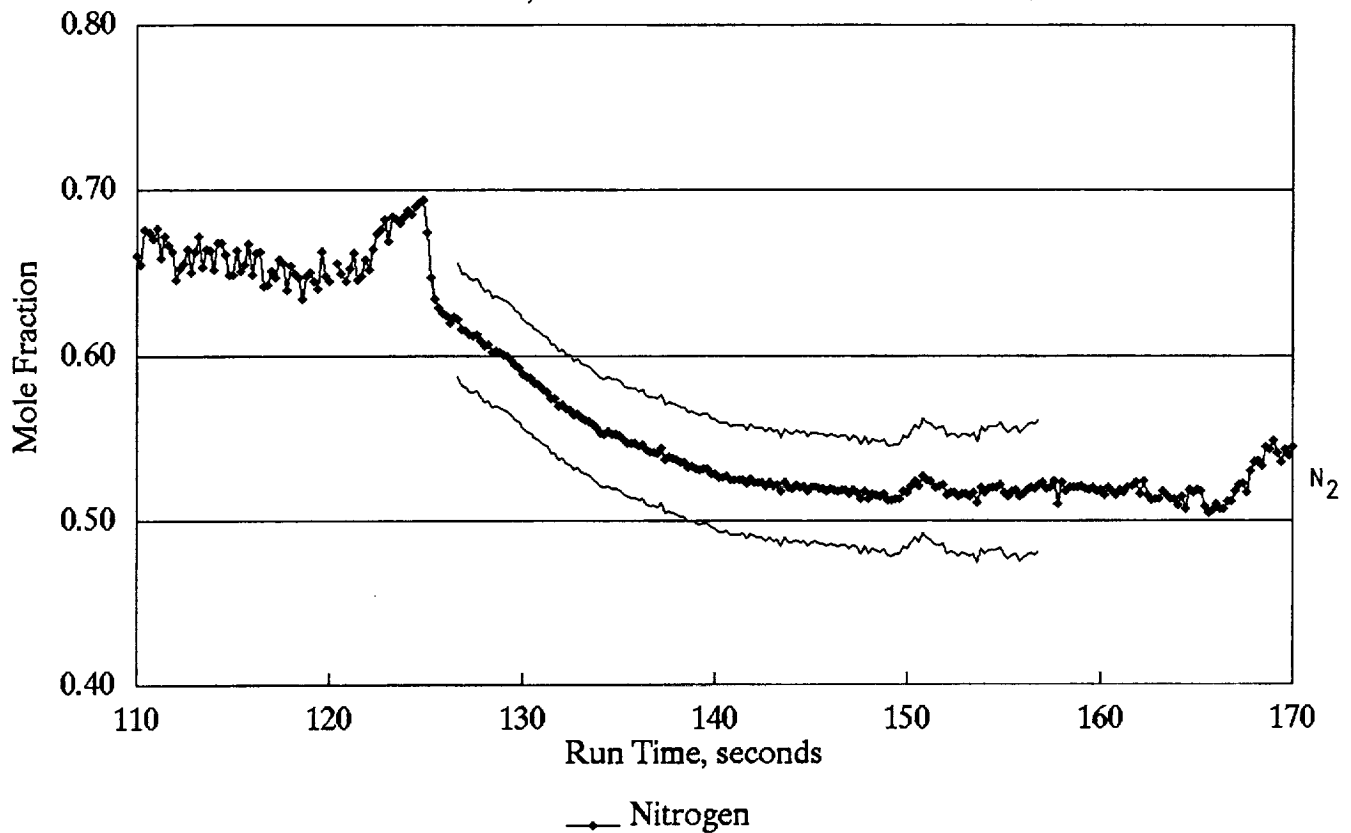
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.201 +/- 0.013

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

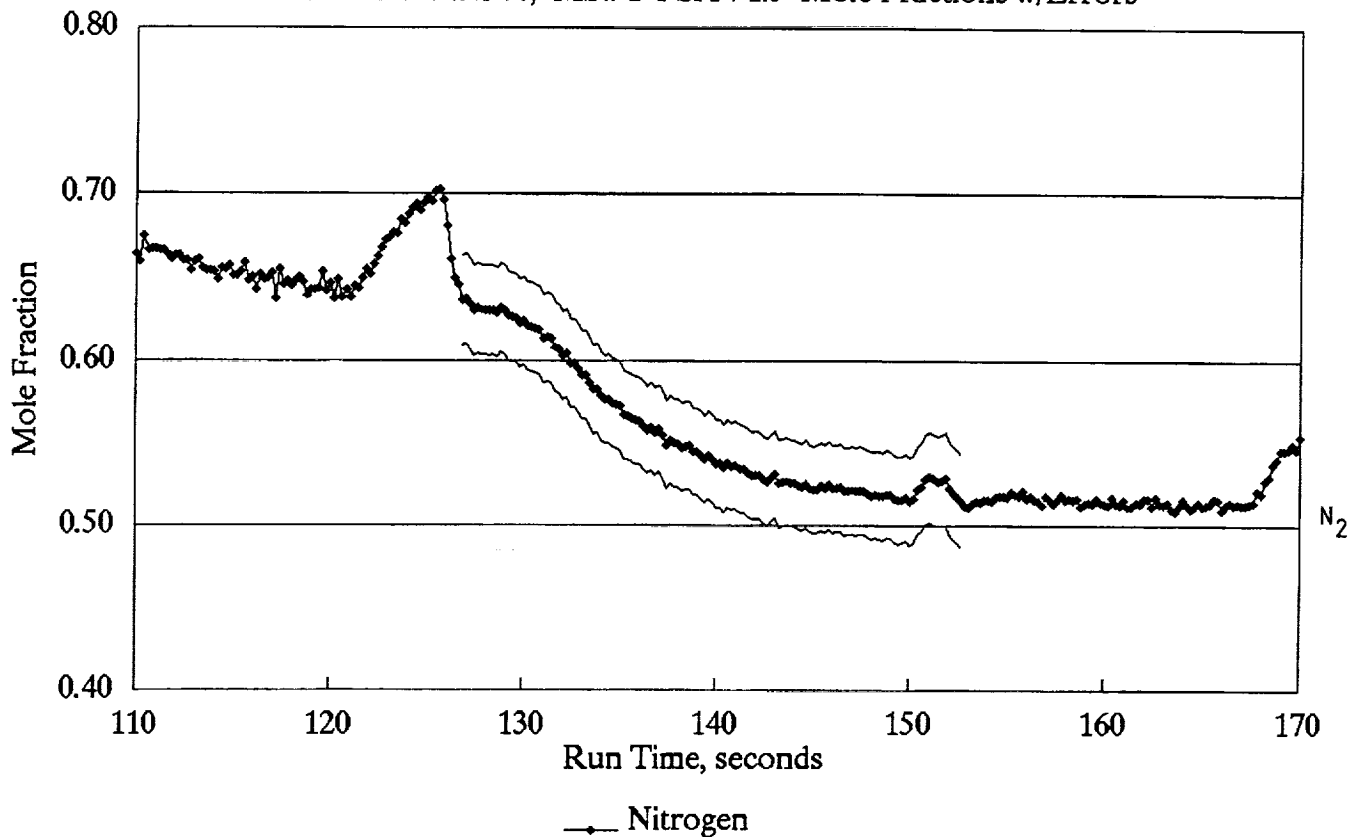
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.520 +/- 0.033

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

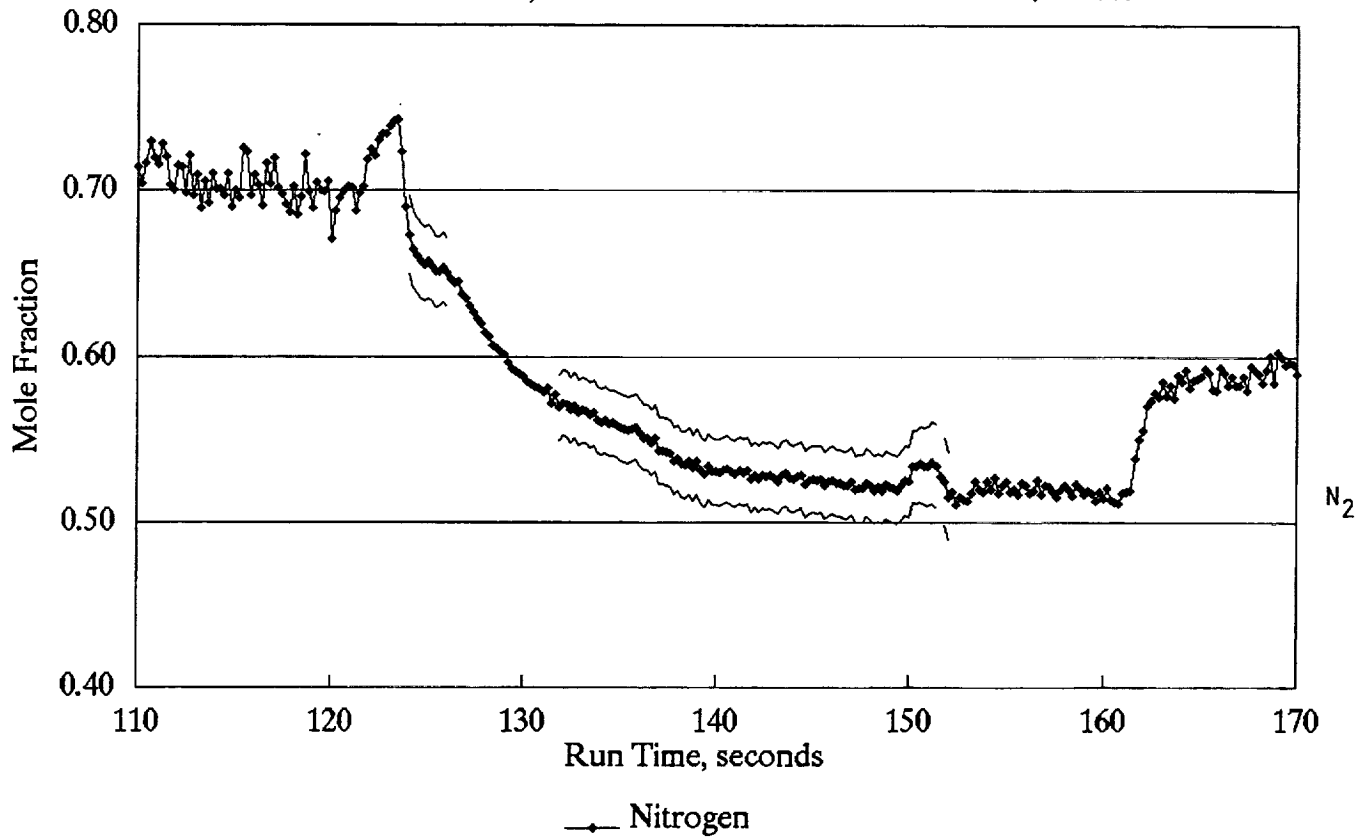
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.525 +/- 0.026

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

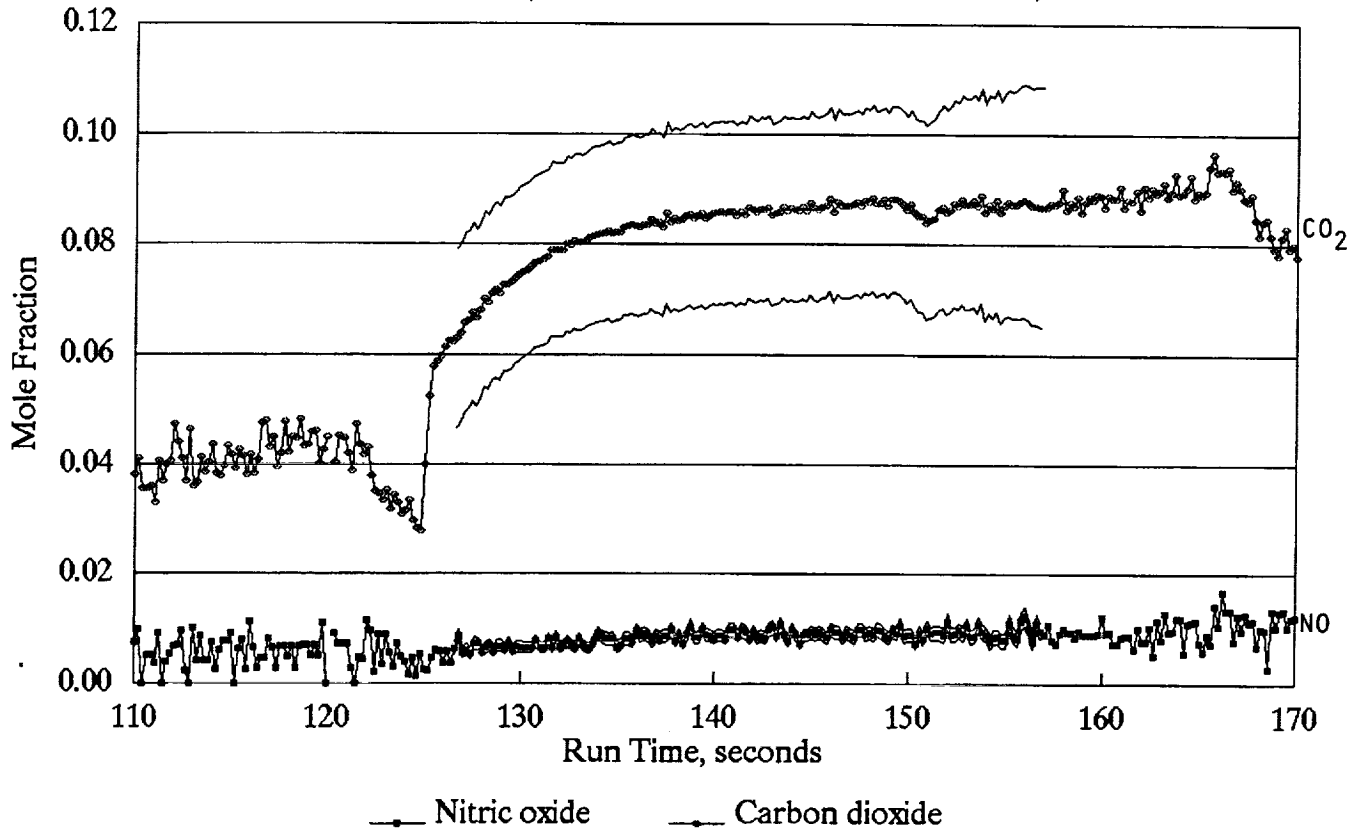
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.526 +/- 0.020

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

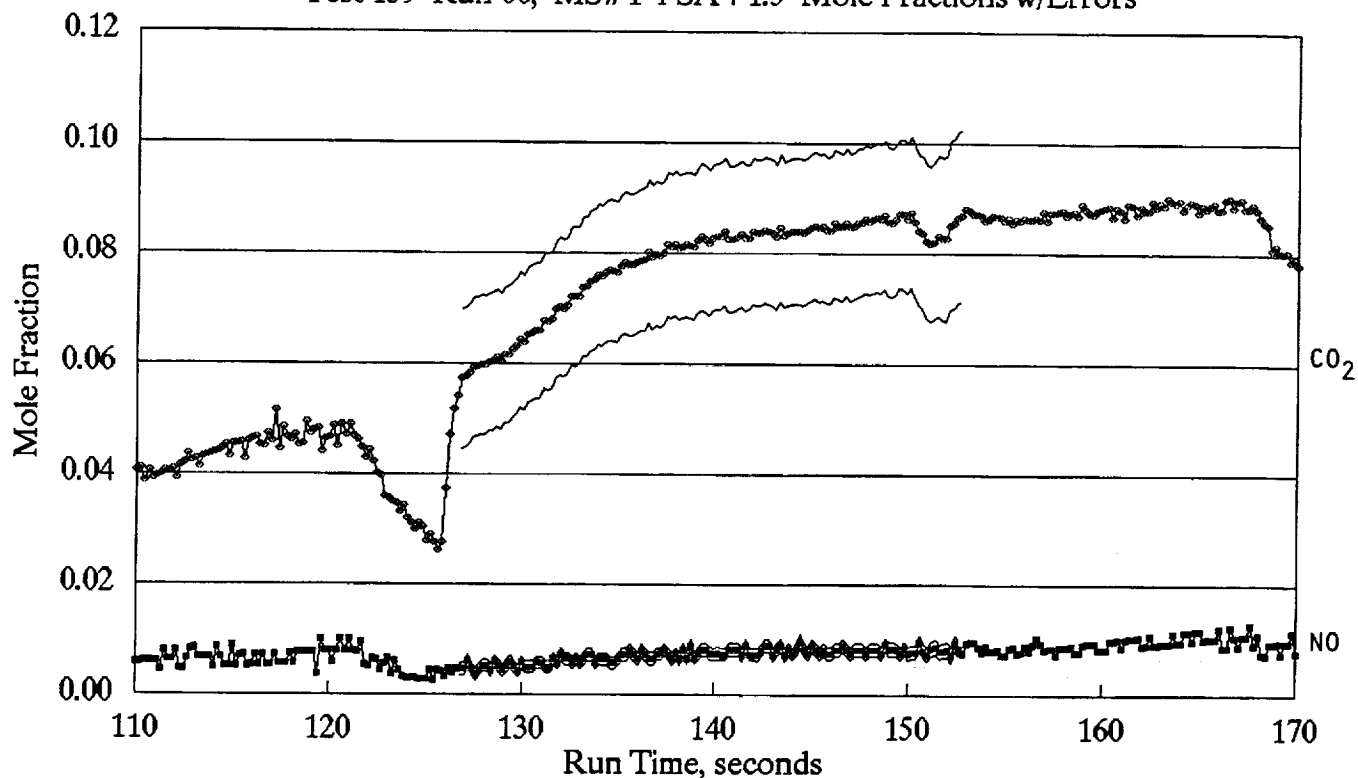
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.087	+/-	0.017
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

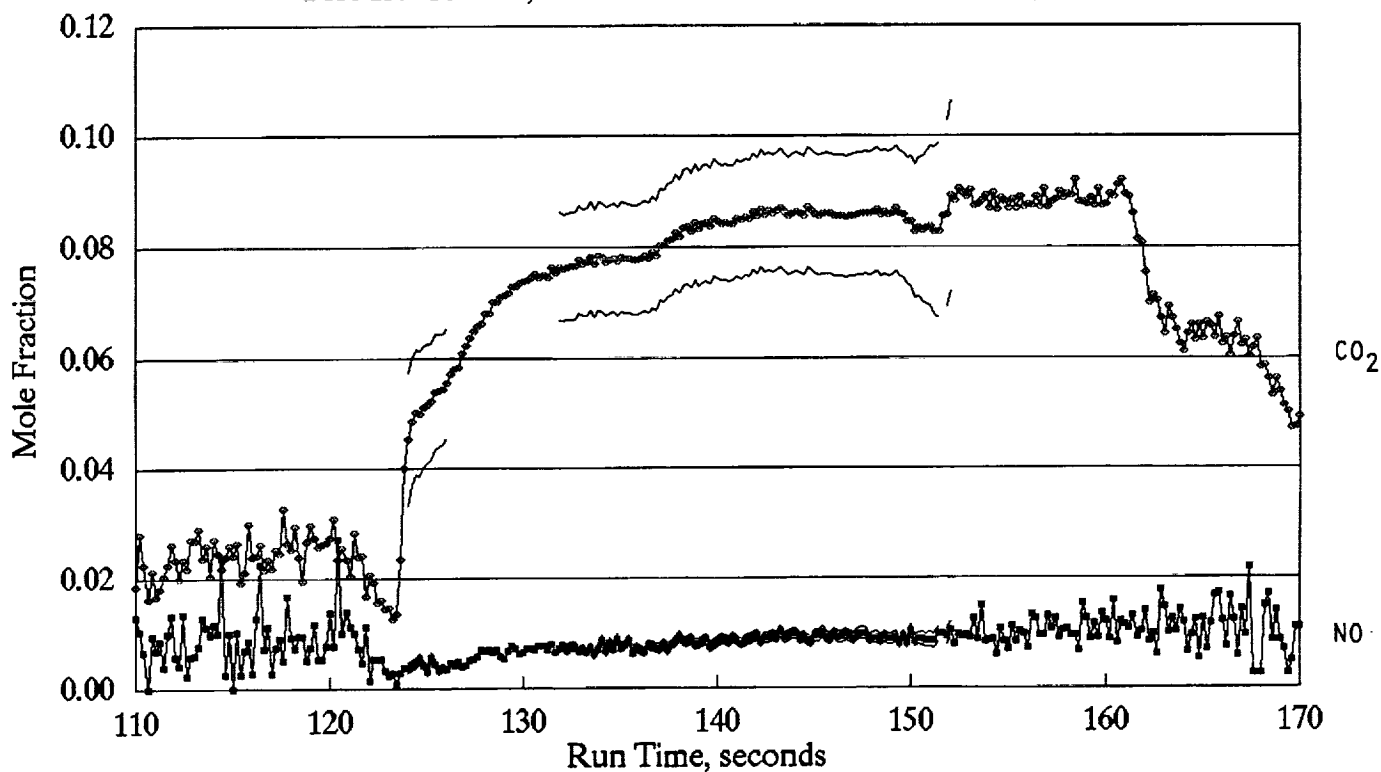
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.085	+/-	0.013
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

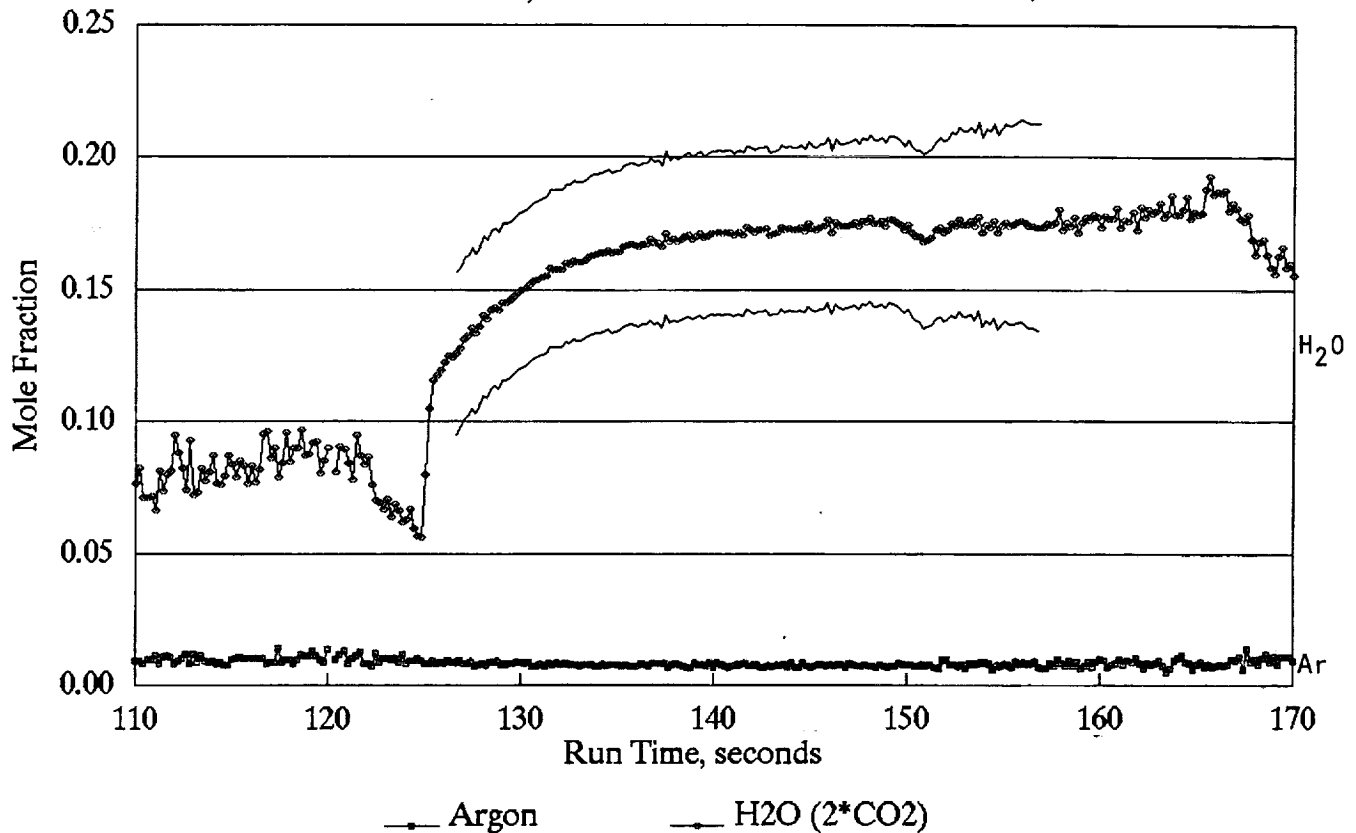
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.086	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

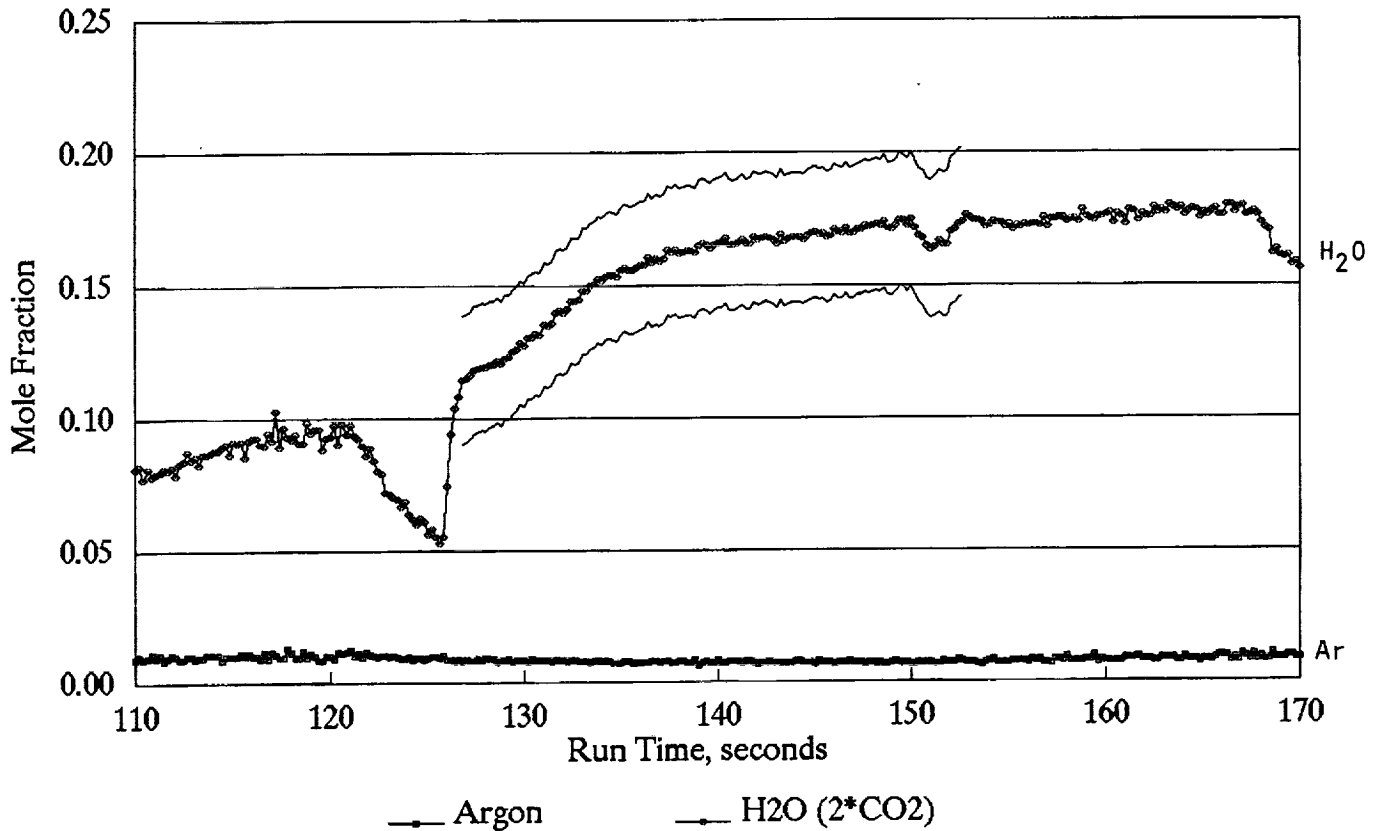
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.173	+/-	0.031

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

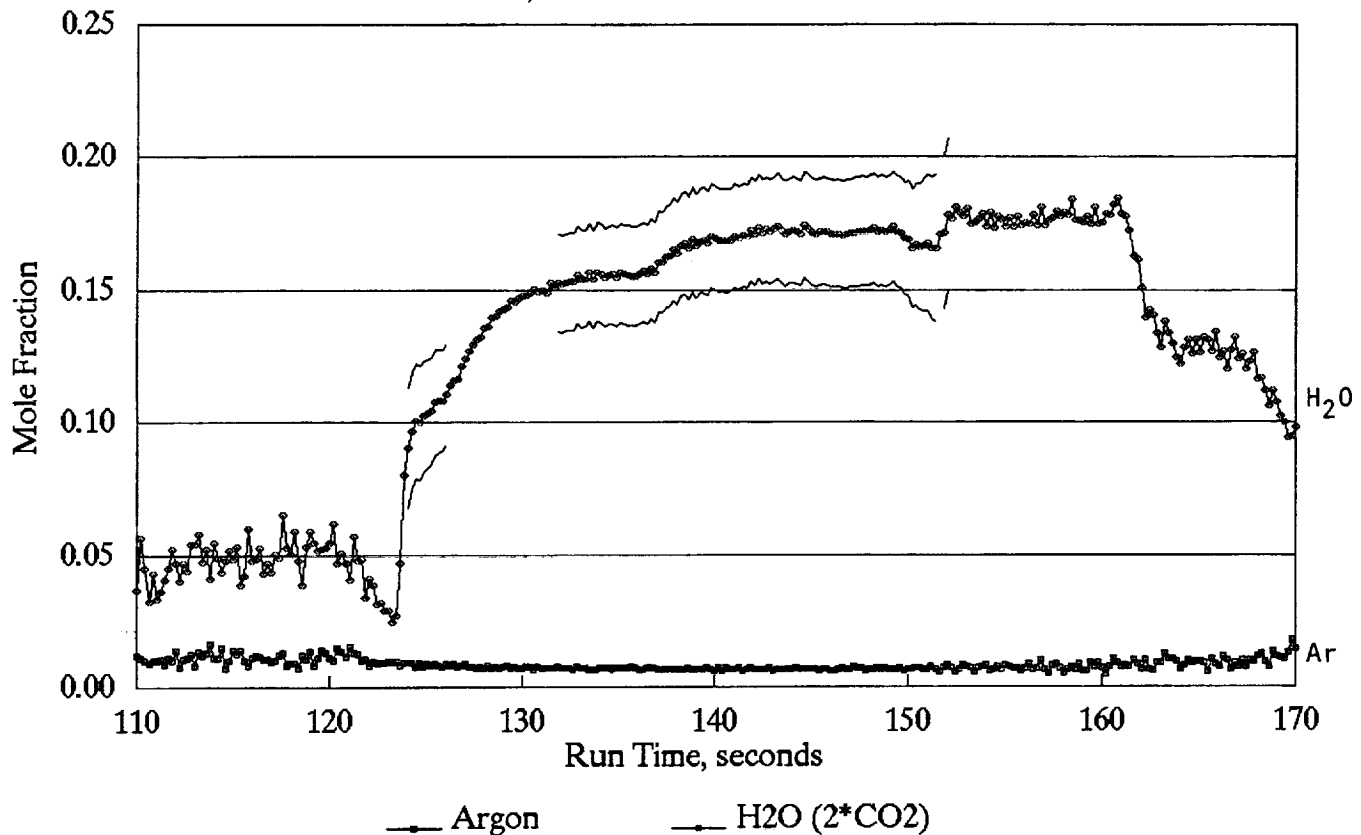
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.169	+/-	0.025

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

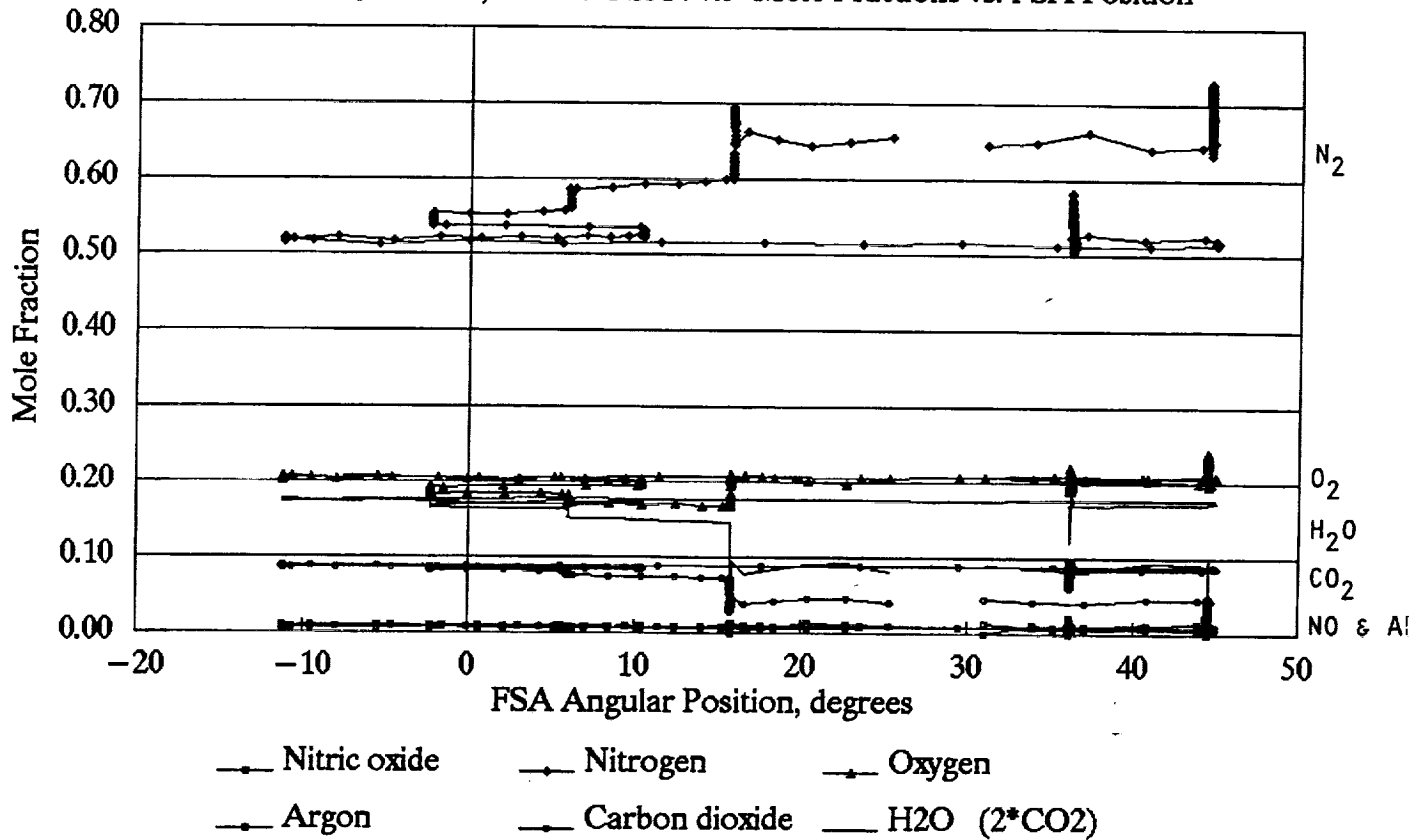
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.172	+/-	0.020

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

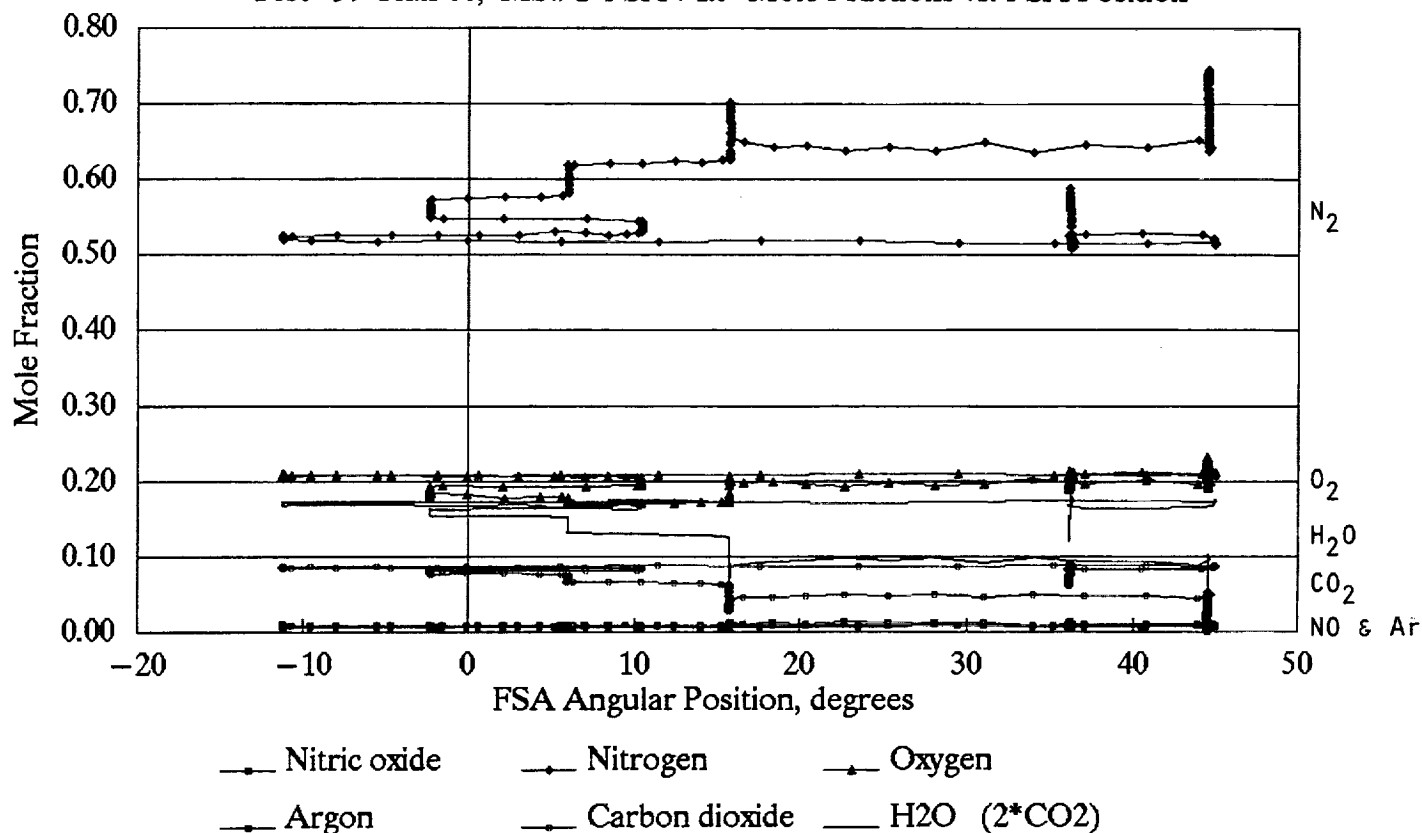
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.520	+/-	0.033
Oxygen:	0.204	+/-	0.022
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.087	+/-	0.017
H2O:	0.173	+/-	0.031
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



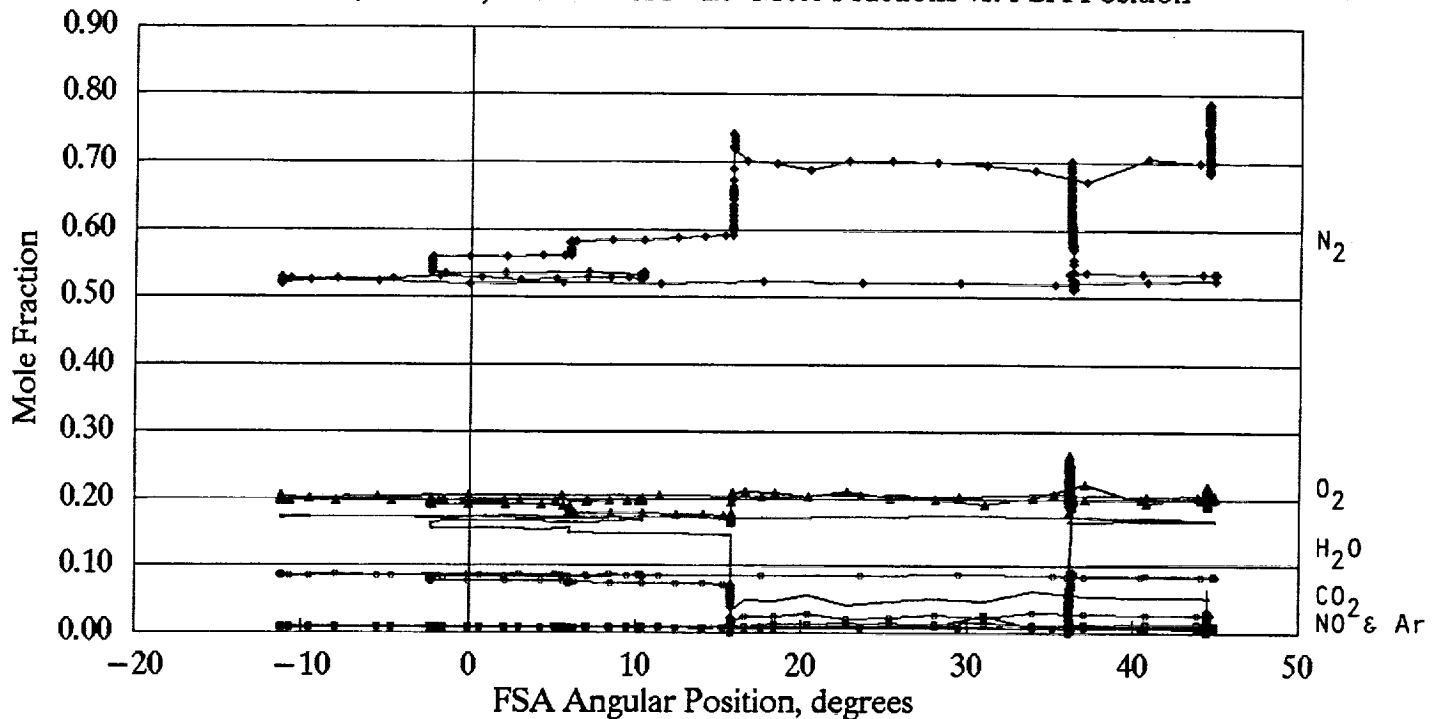
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.525	+/-	0.026
Oxygen:	0.206	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.085	+/-	0.013
H2O:	0.169	+/-	0.025
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

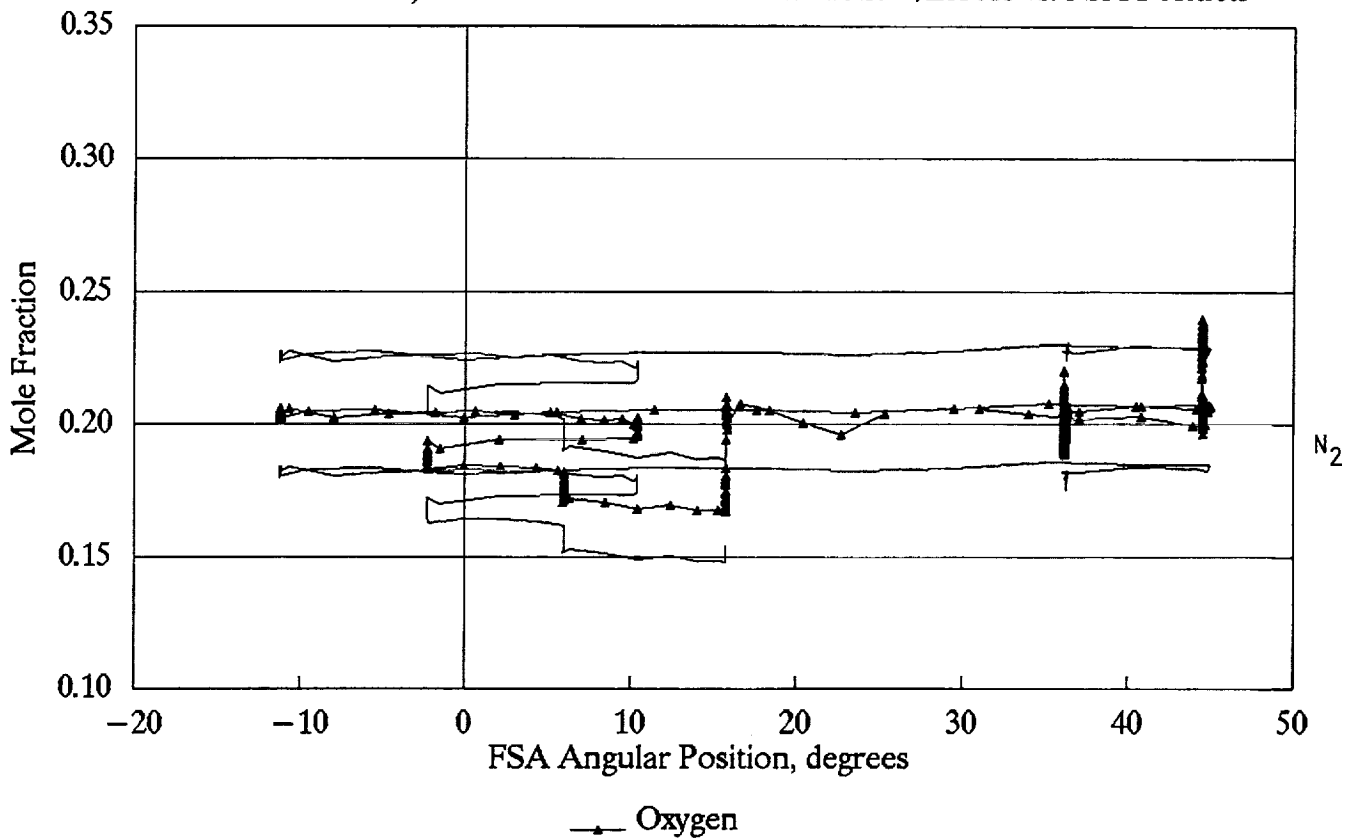
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.526	+/-	0.020
Oxygen:	0.201	+/-	0.013
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.086	+/-	0.011
H2O:	0.172	+/-	0.020
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA +7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

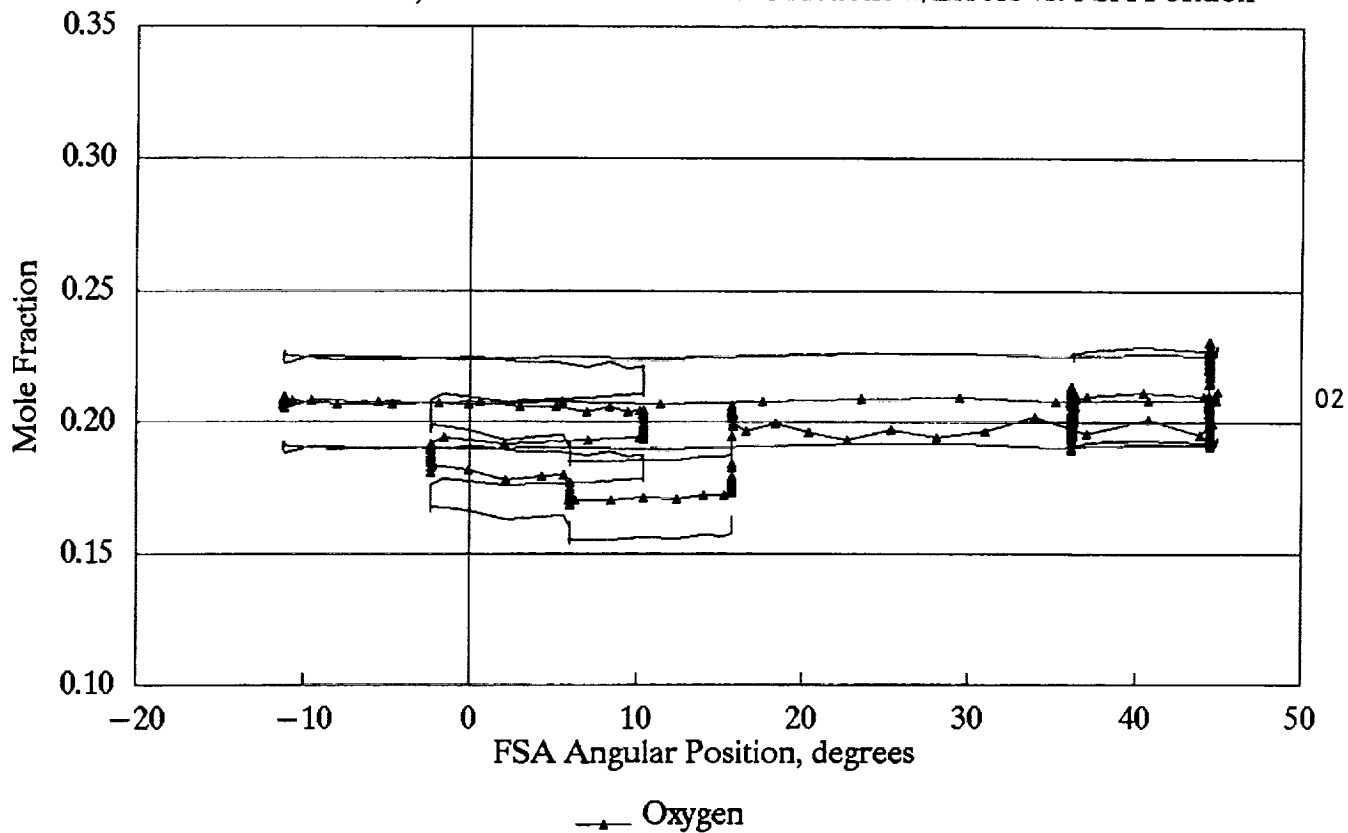
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.204 +/- 0.022

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA + 1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

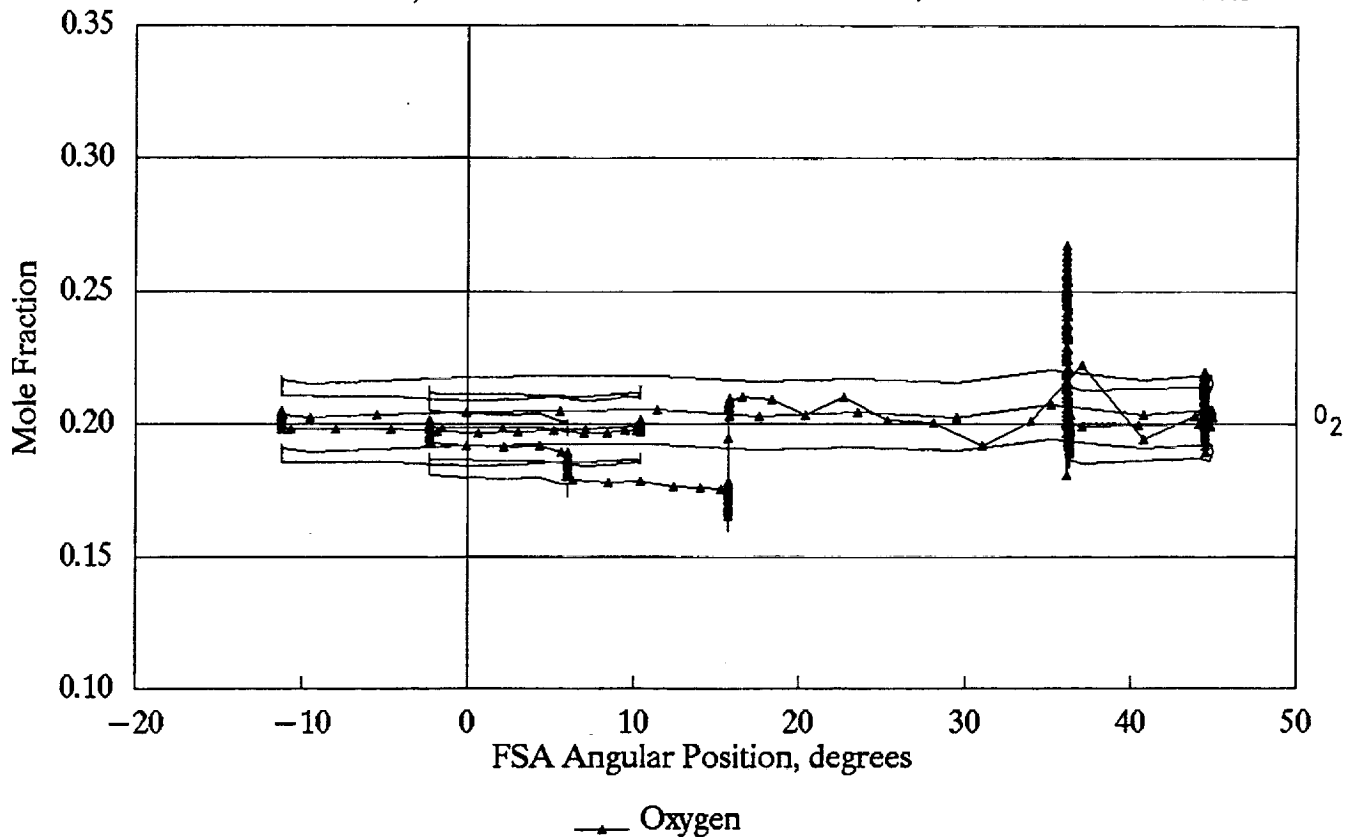
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.206 +/- 0.017

8' HTT Gas Analysis System

Test 13 9 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

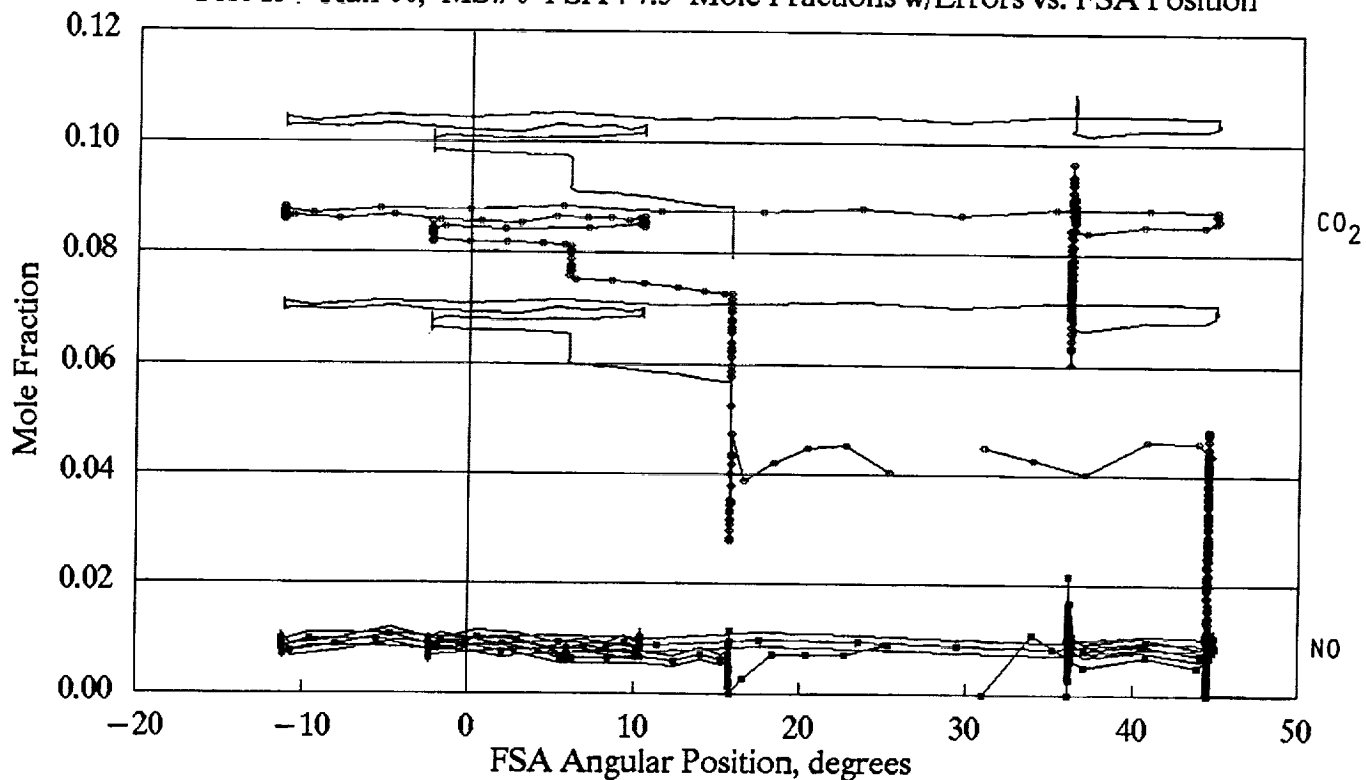
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.201 +/- 0.013

8' HTT Gas Analysis System

Test 139 Run 06, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

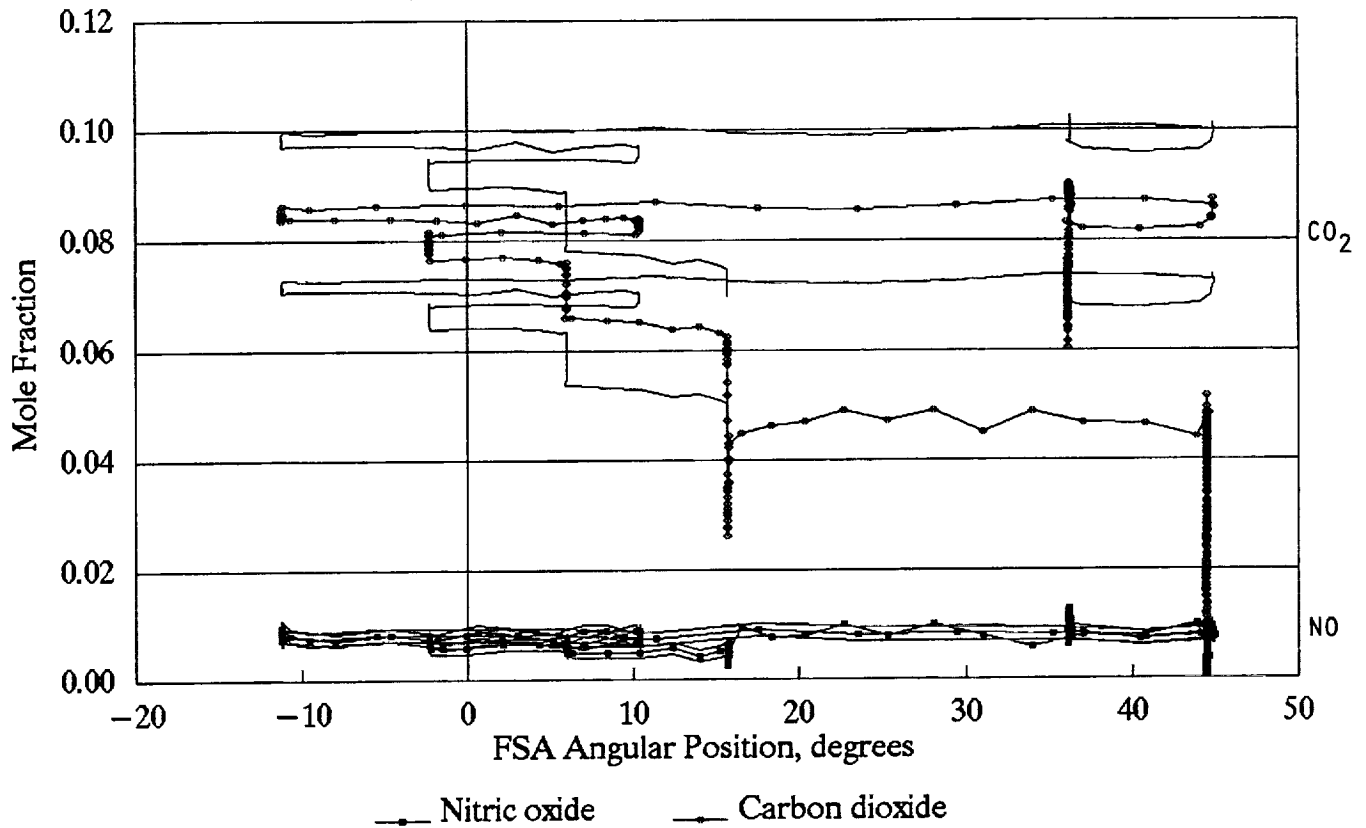
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.087	+/-	0.017
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

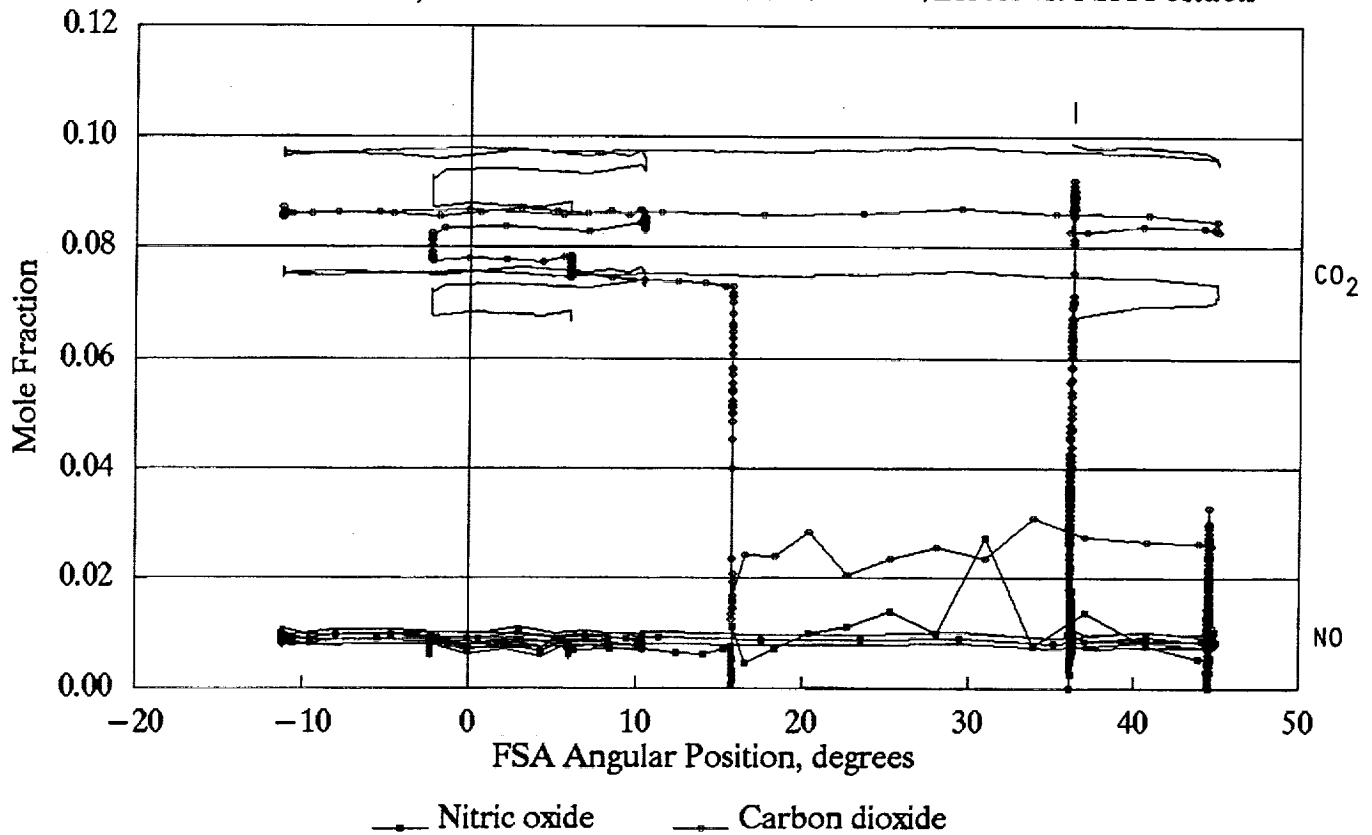
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.085	+/-	0.013
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

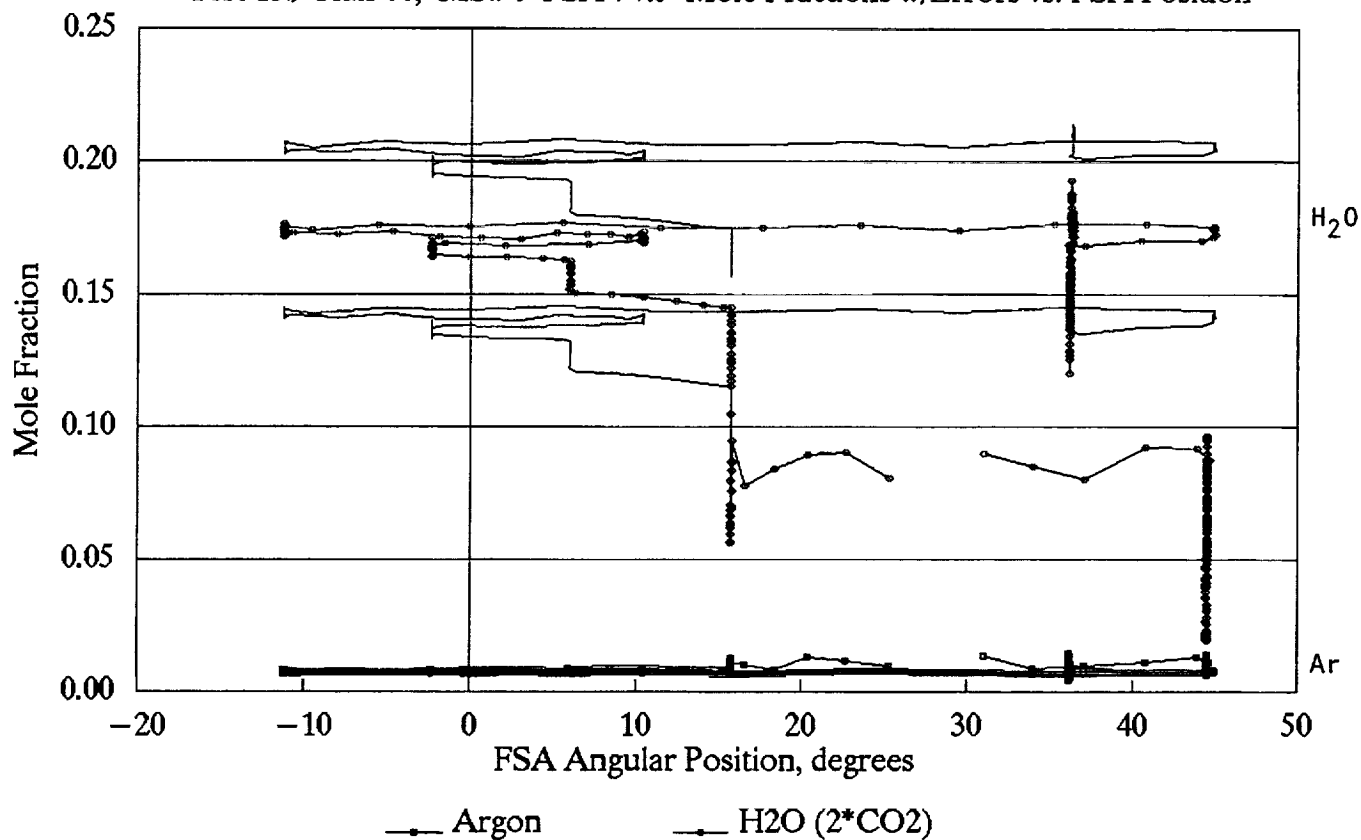
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.086	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13.9 Run 06, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

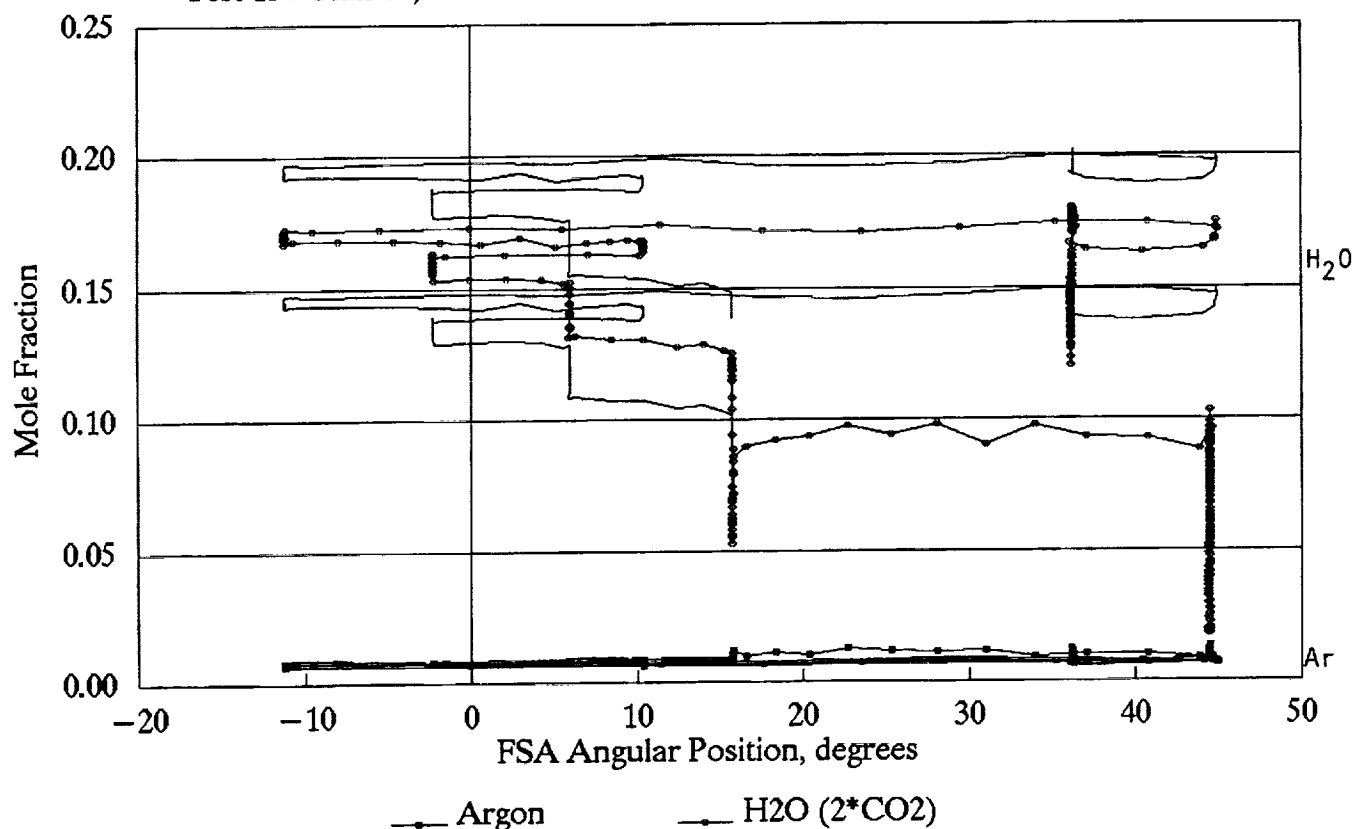
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.173	+/-	0.031

8' HTT Gas Analysis System

Test 139 Run 06, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

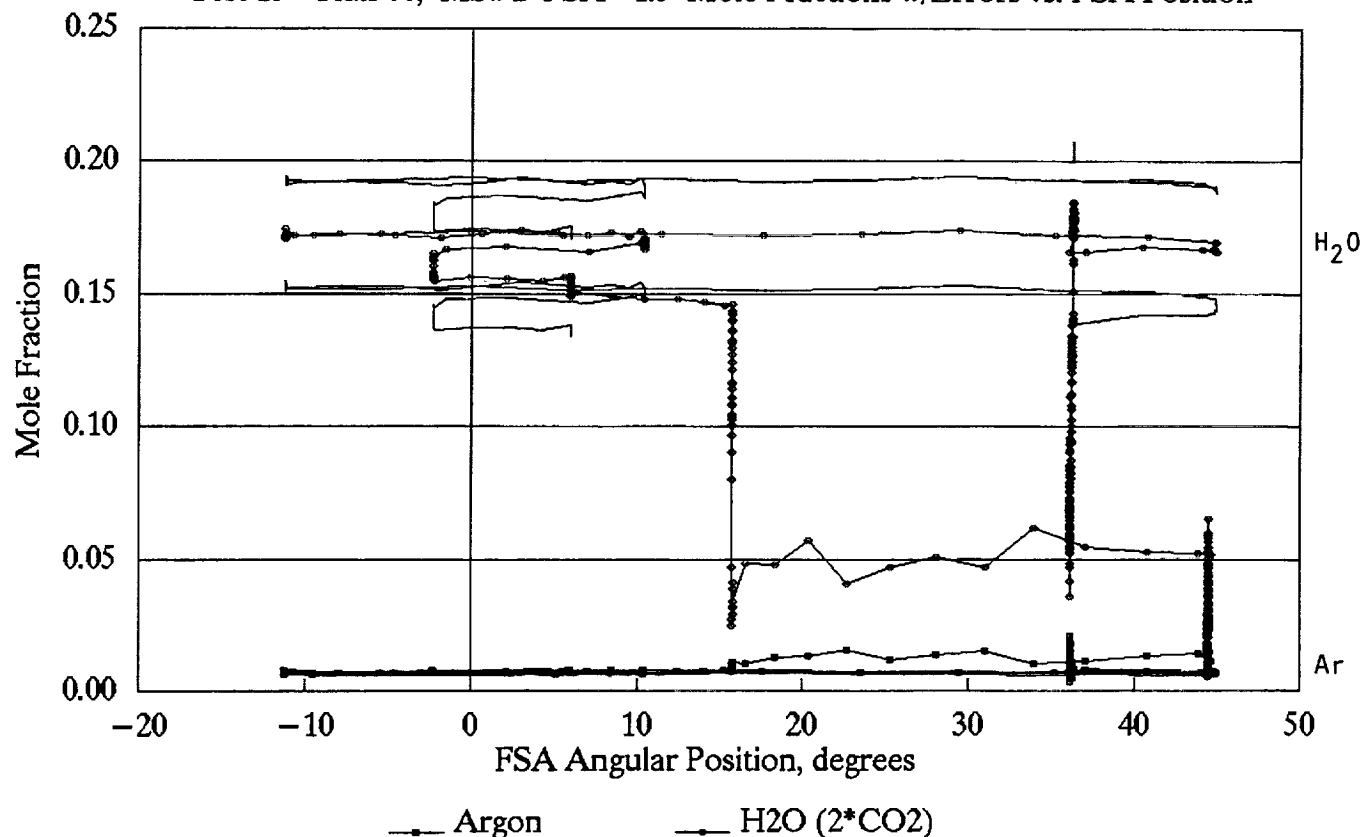
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.169	+/-	0.025

8' HTT Gas Analysis System

Test 13⁹ Run 06, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.172	+/-	0.020

Test 139 Run 12

Combustor Pressure: 2000 psia

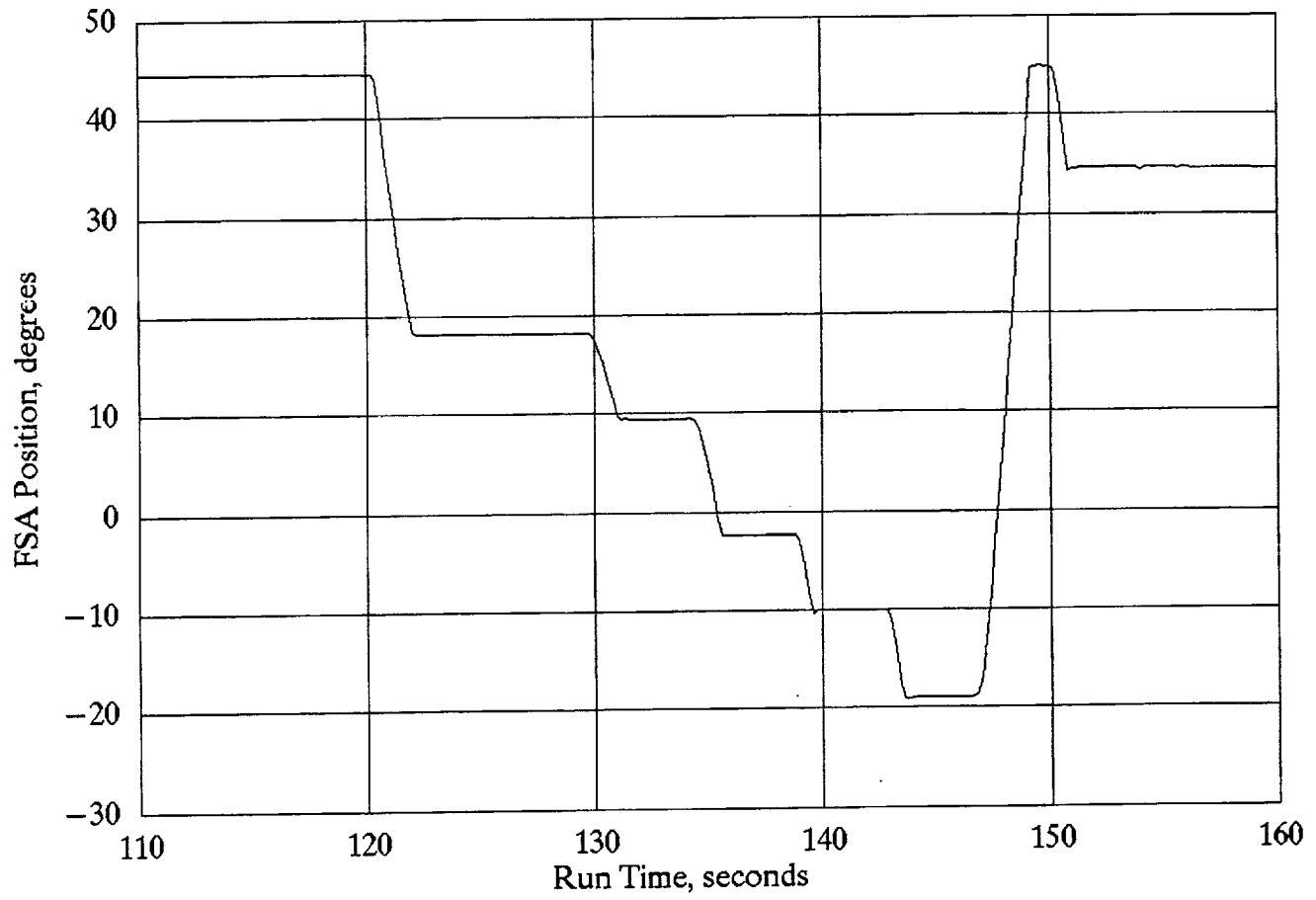
Combustor Temperature: 3400 R

Normal Stop: 149.5 seconds

Probes: FSA+1.5, FSA-1.5

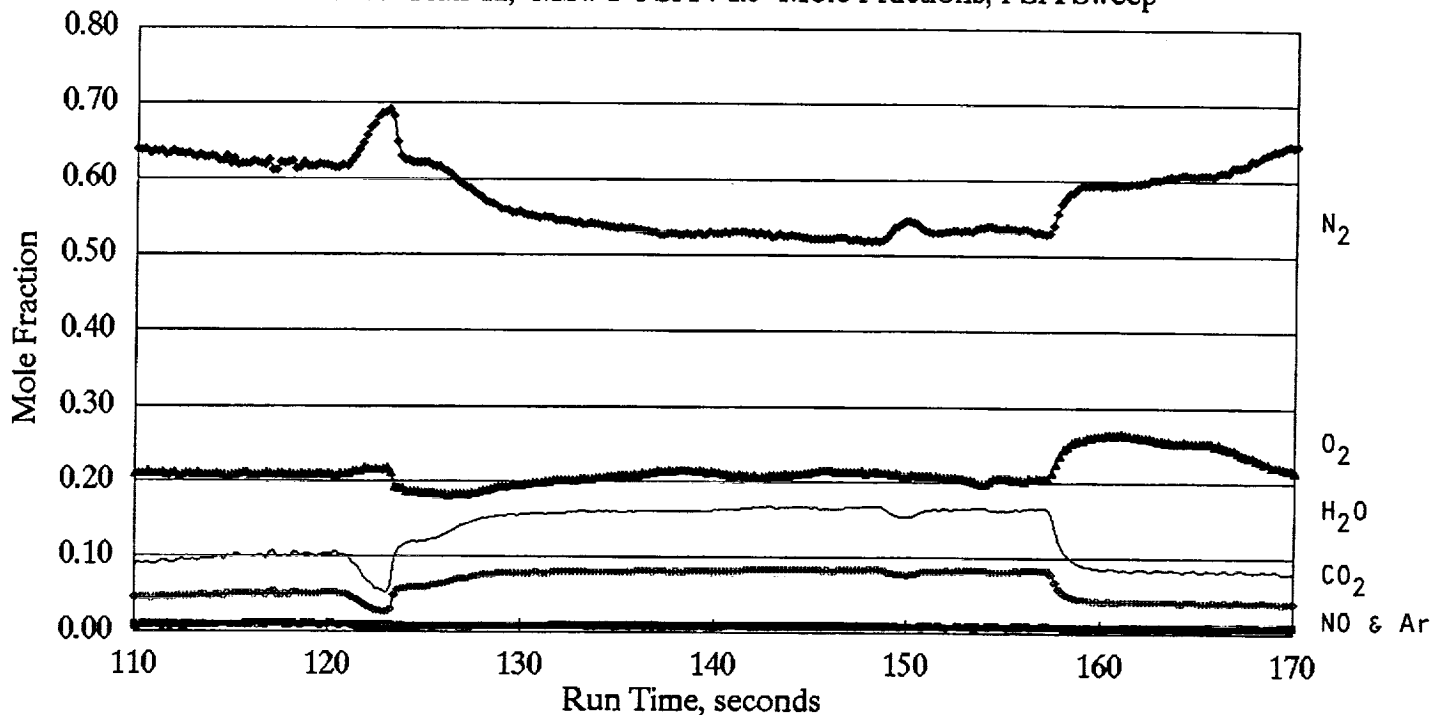
8' HTT Gas Analysis System

FSA Position, Test 139 Run 12



8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

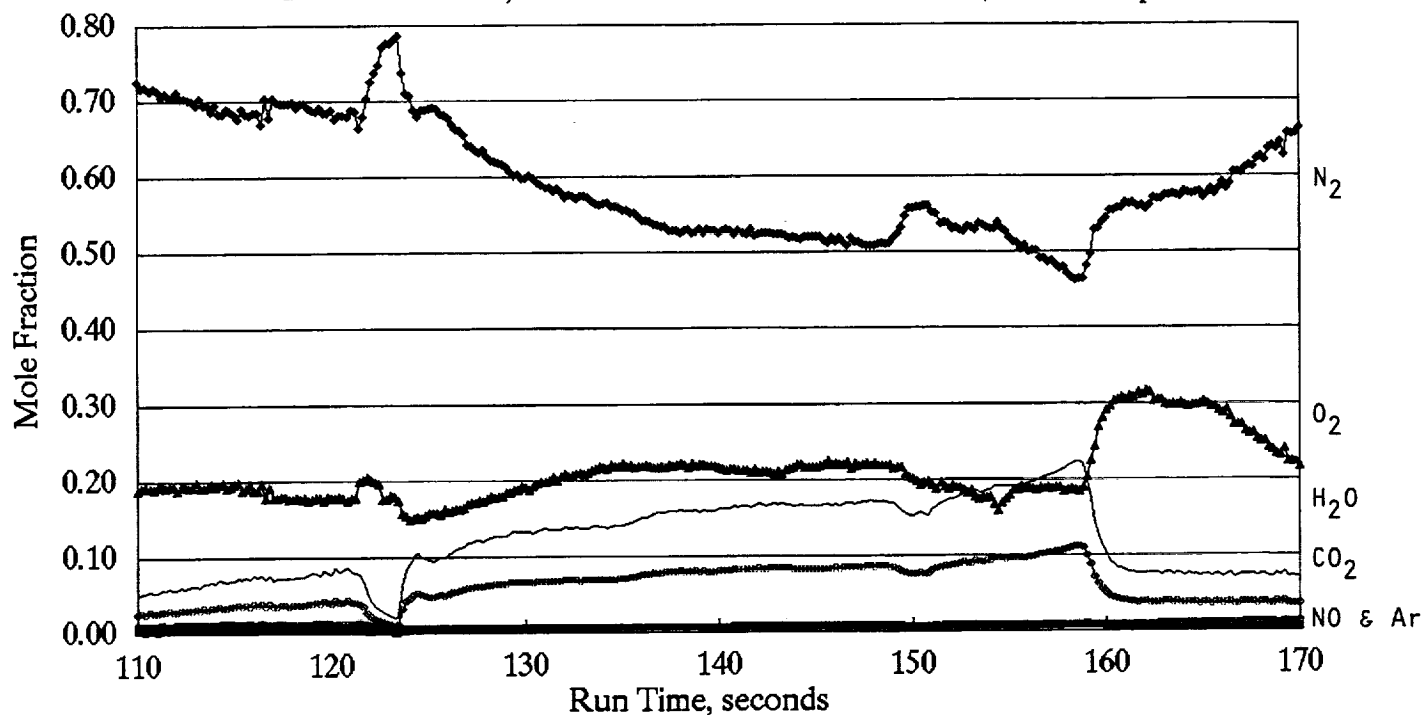
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.529	+/-	0.035
Oxygen:	0.210	+/-	0.026
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.012
H2O:	0.162	+/-	0.023
Nitric oxide:	0.010	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

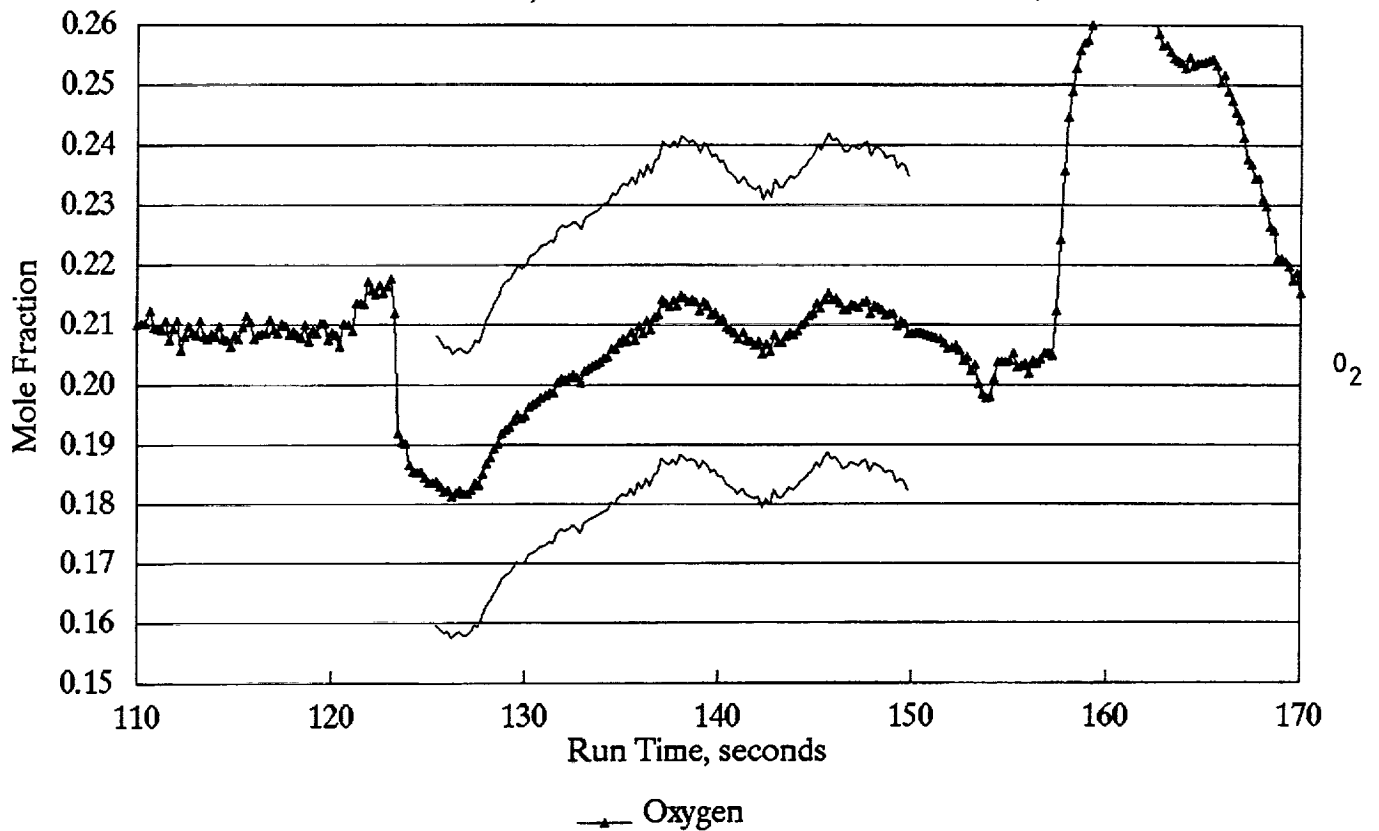
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.530	+/-	0.052
Oxygen:	0.216	+/-	0.031
Argon:	0.006	+/-	0.001
Carbon dioxide:	0.080	+/-	0.014
H2O:	0.160	+/-	0.024
Nitric oxide:	0.007	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors



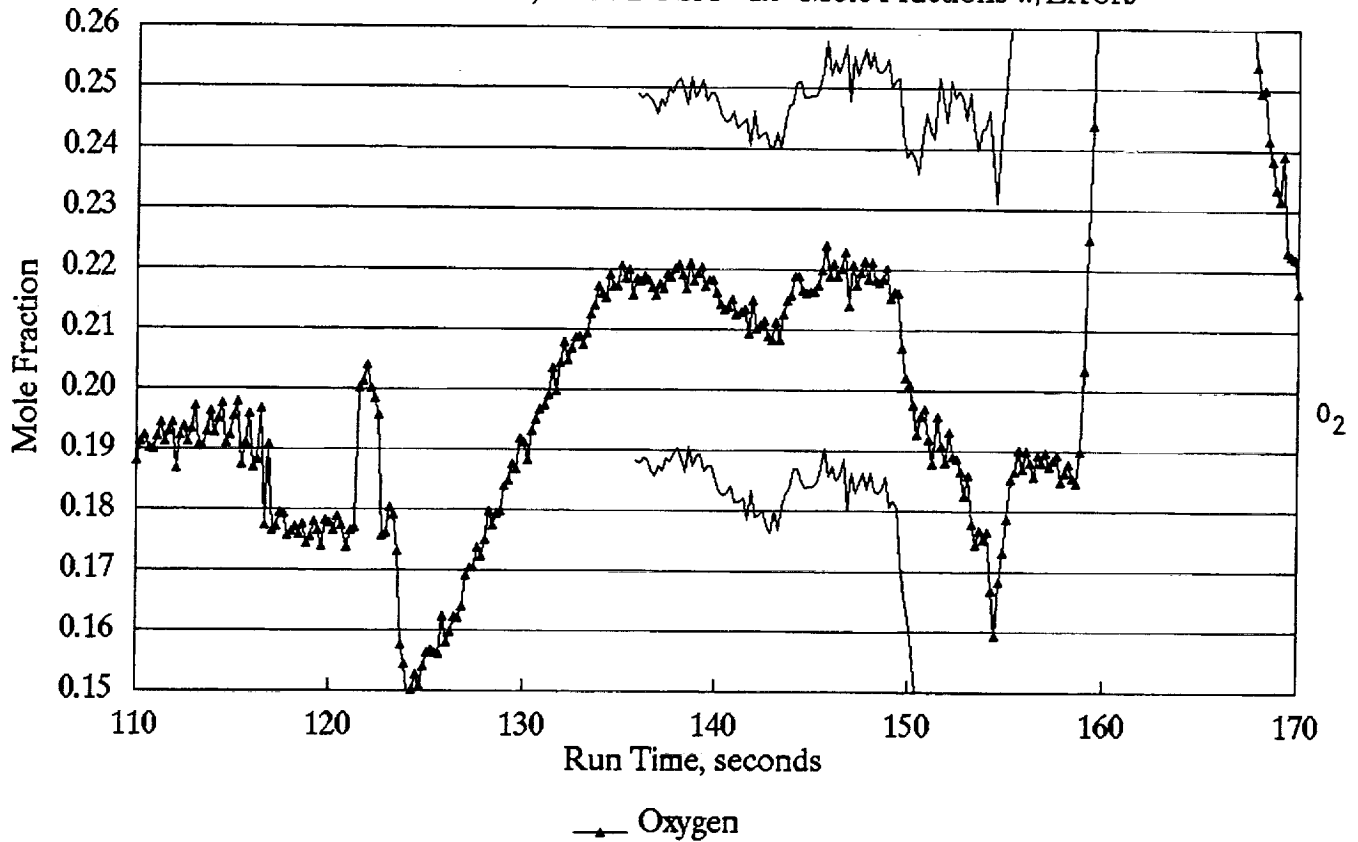
Errors given at 95% level of confidence.

CO₂ fragmentation coefficient: 0.0817.
Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.210 +/- 0.026

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

Based on calibrations k60 and k61.

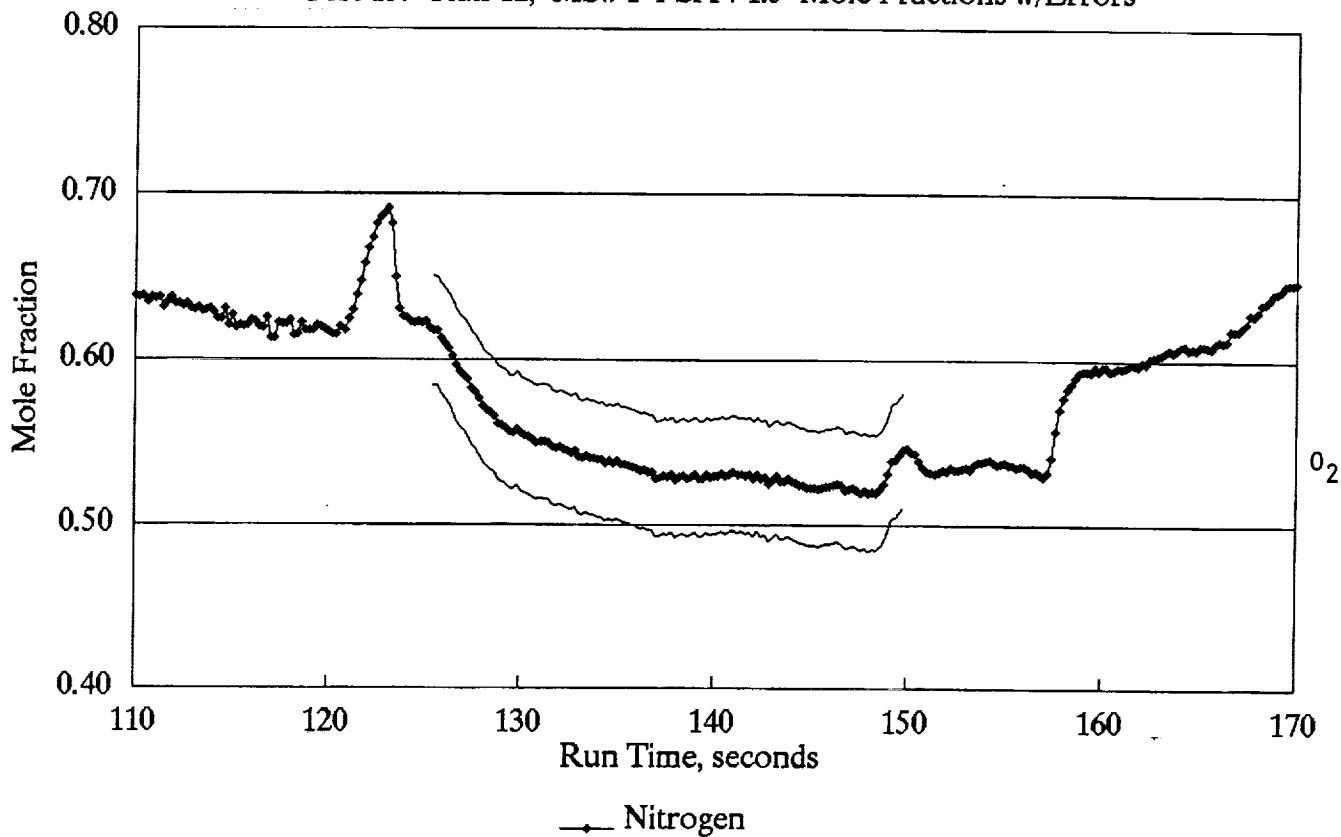
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.216 +/- 0.031

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

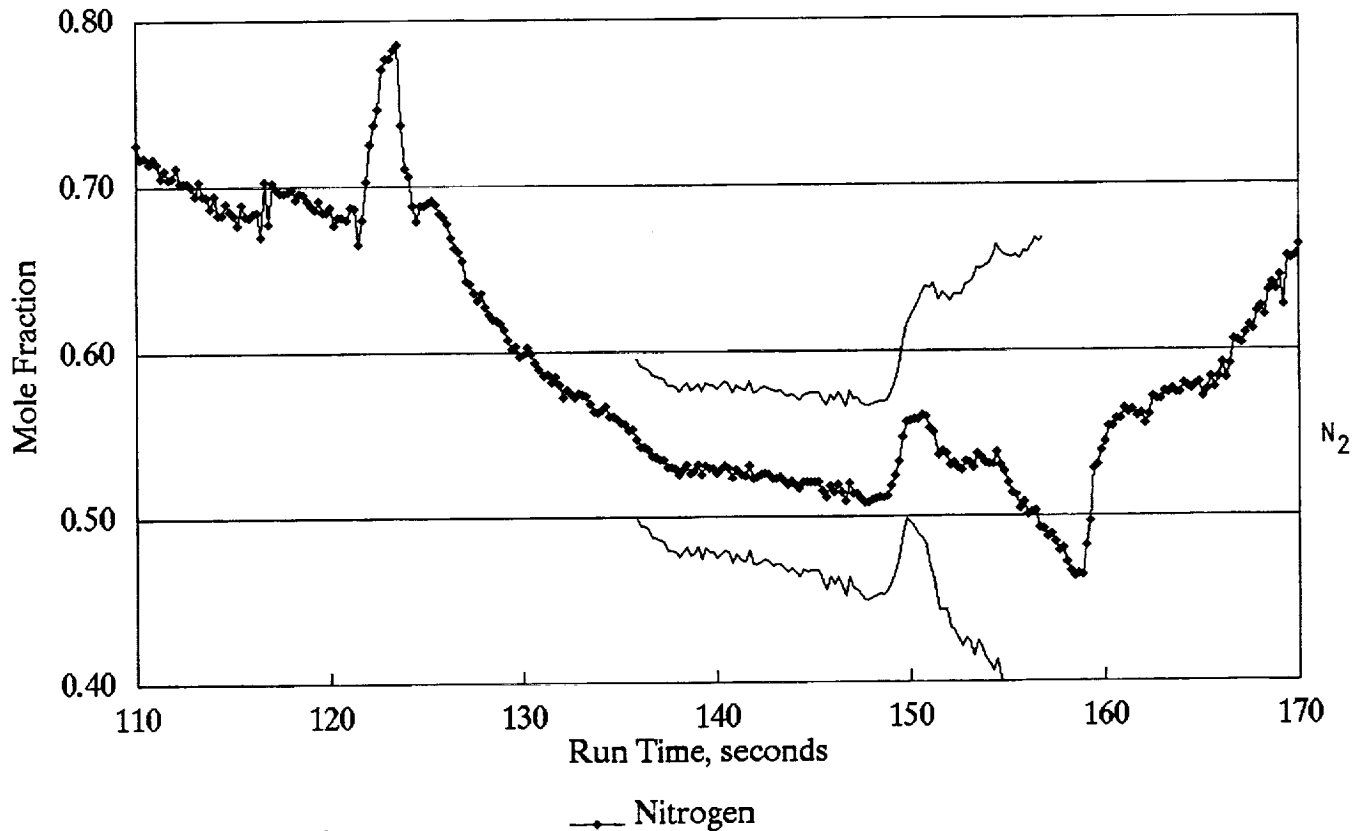
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen: 0.529 +/- 0.035

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

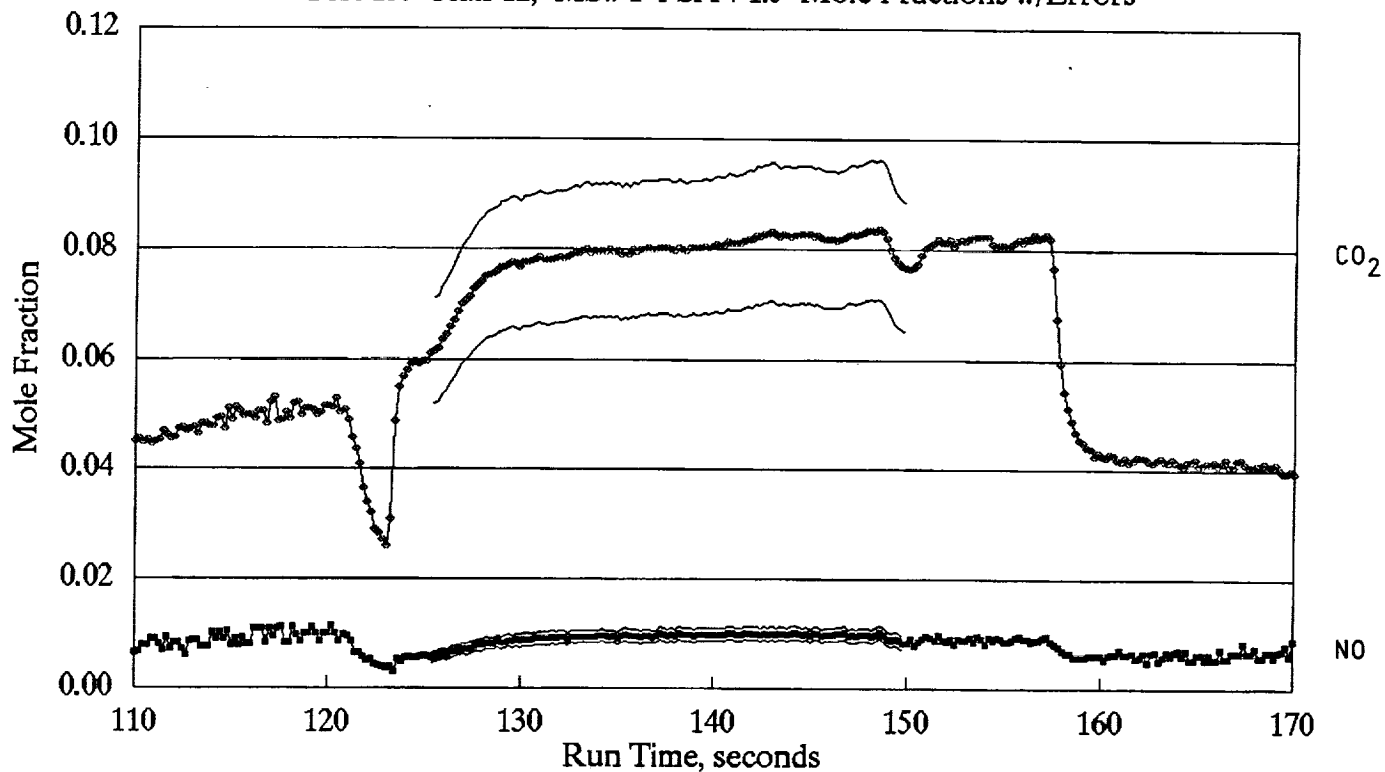
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen: 0.530 +/- 0.052

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

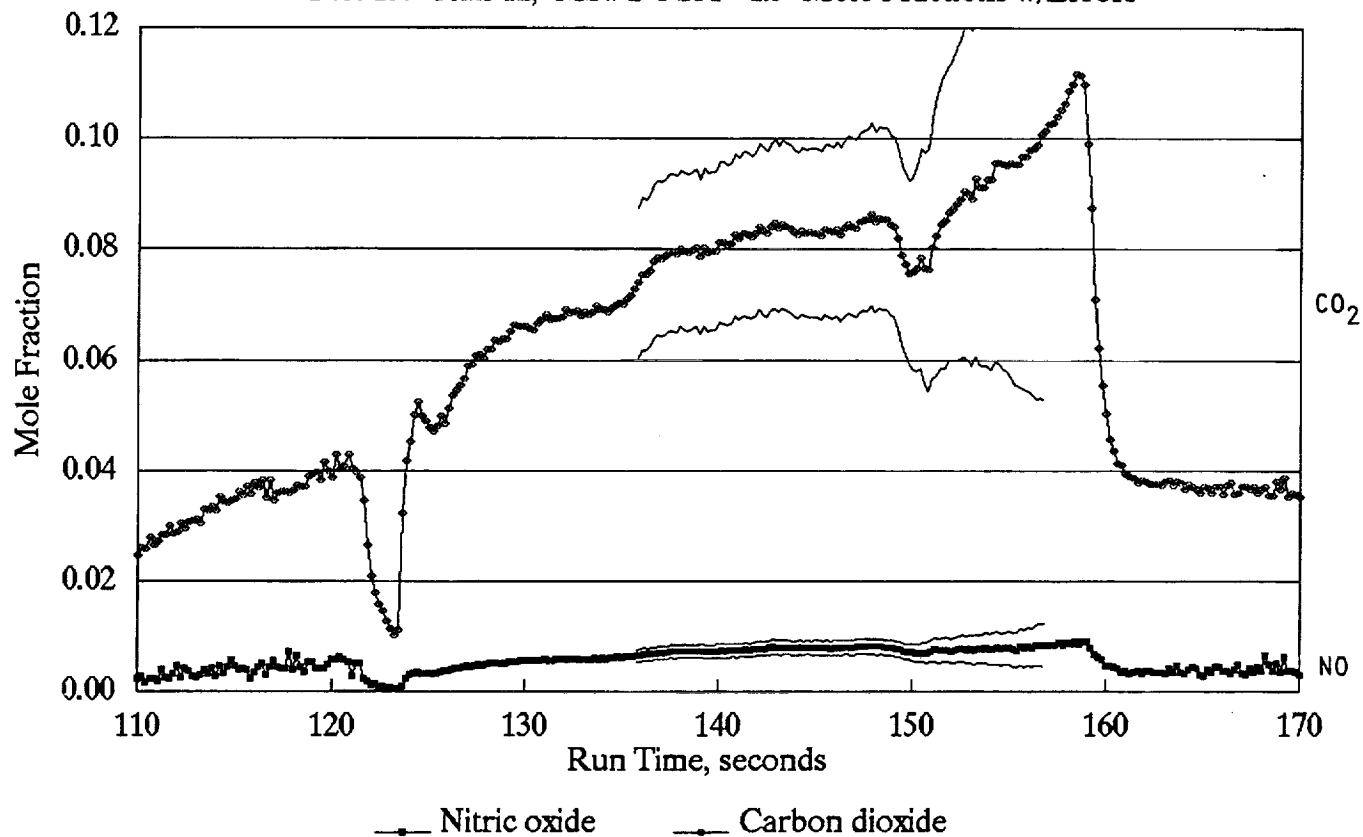
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.081	+/-	0.012
Nitric oxide:	0.010	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

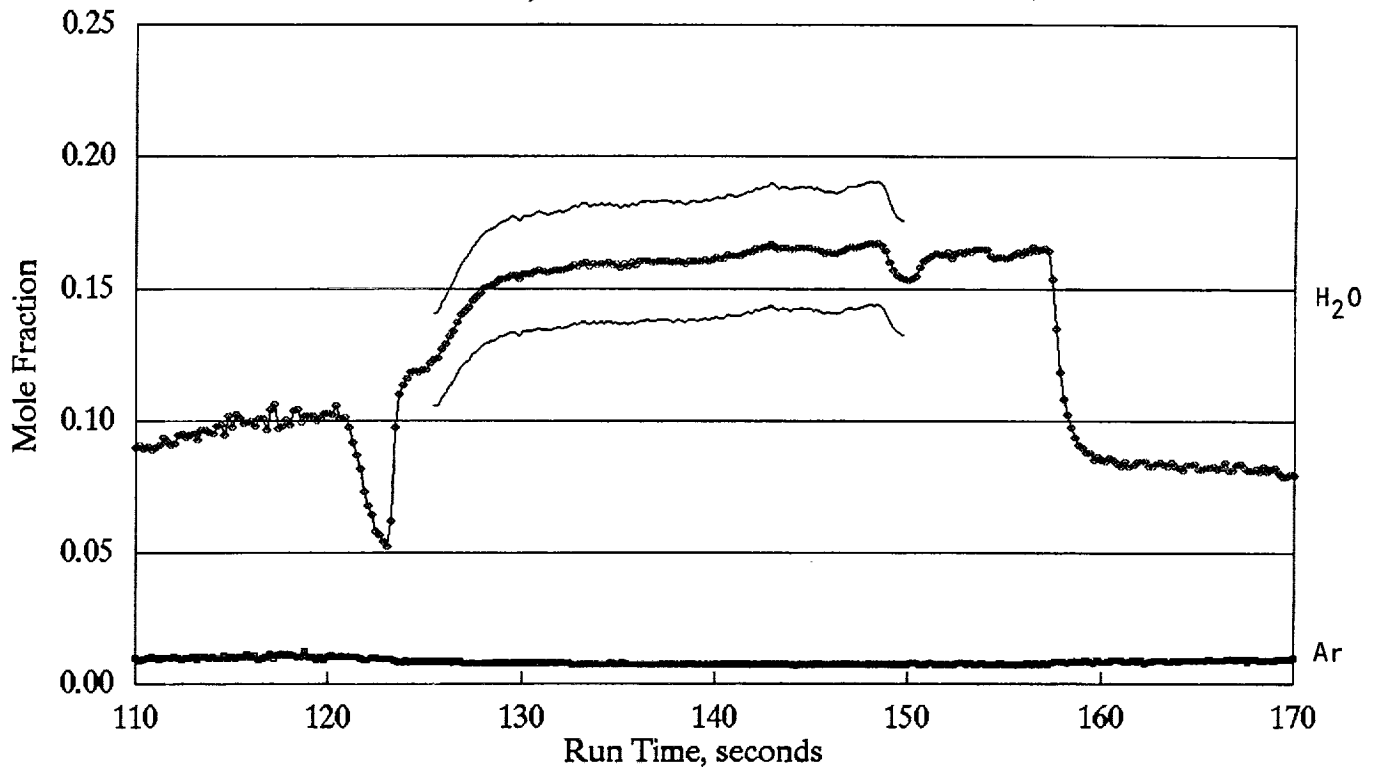
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.080	+/-	0.014
Nitric oxide:	0.007	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors



— Argon — H2O (2*CO2)

Errors given at 95% level of confidence.

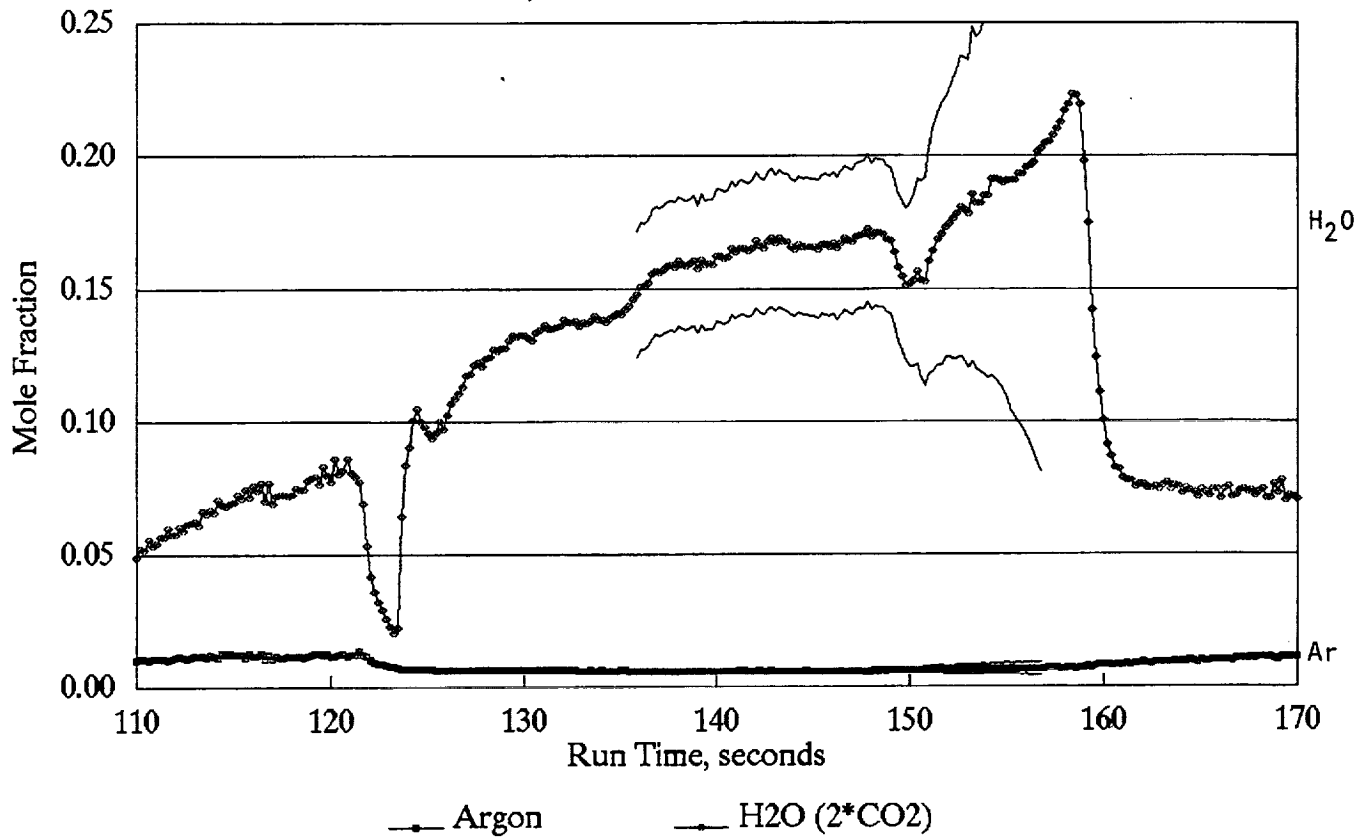
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.023

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

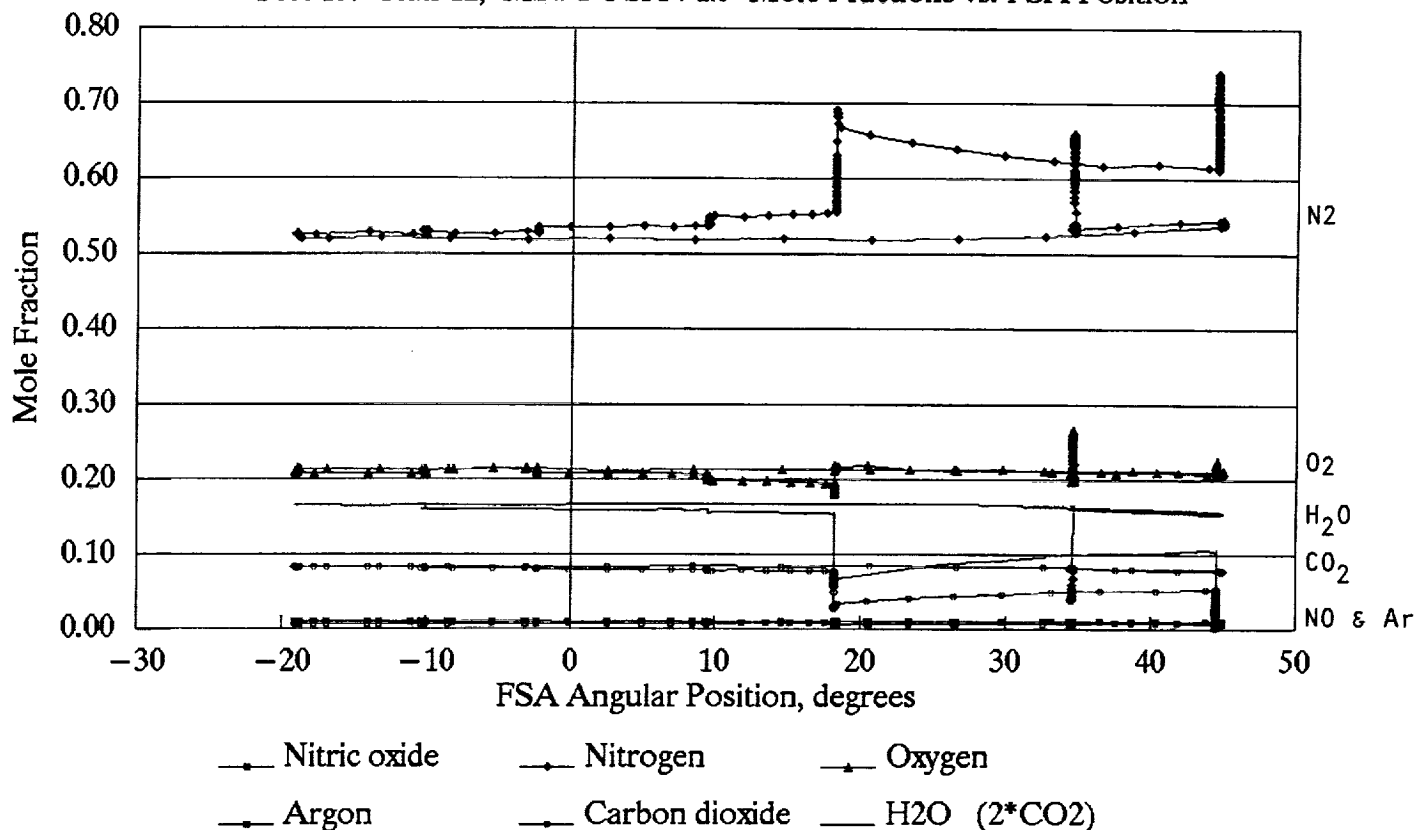
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.006	+/-	0.001
H ₂ O:	0.160	+/-	0.024

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

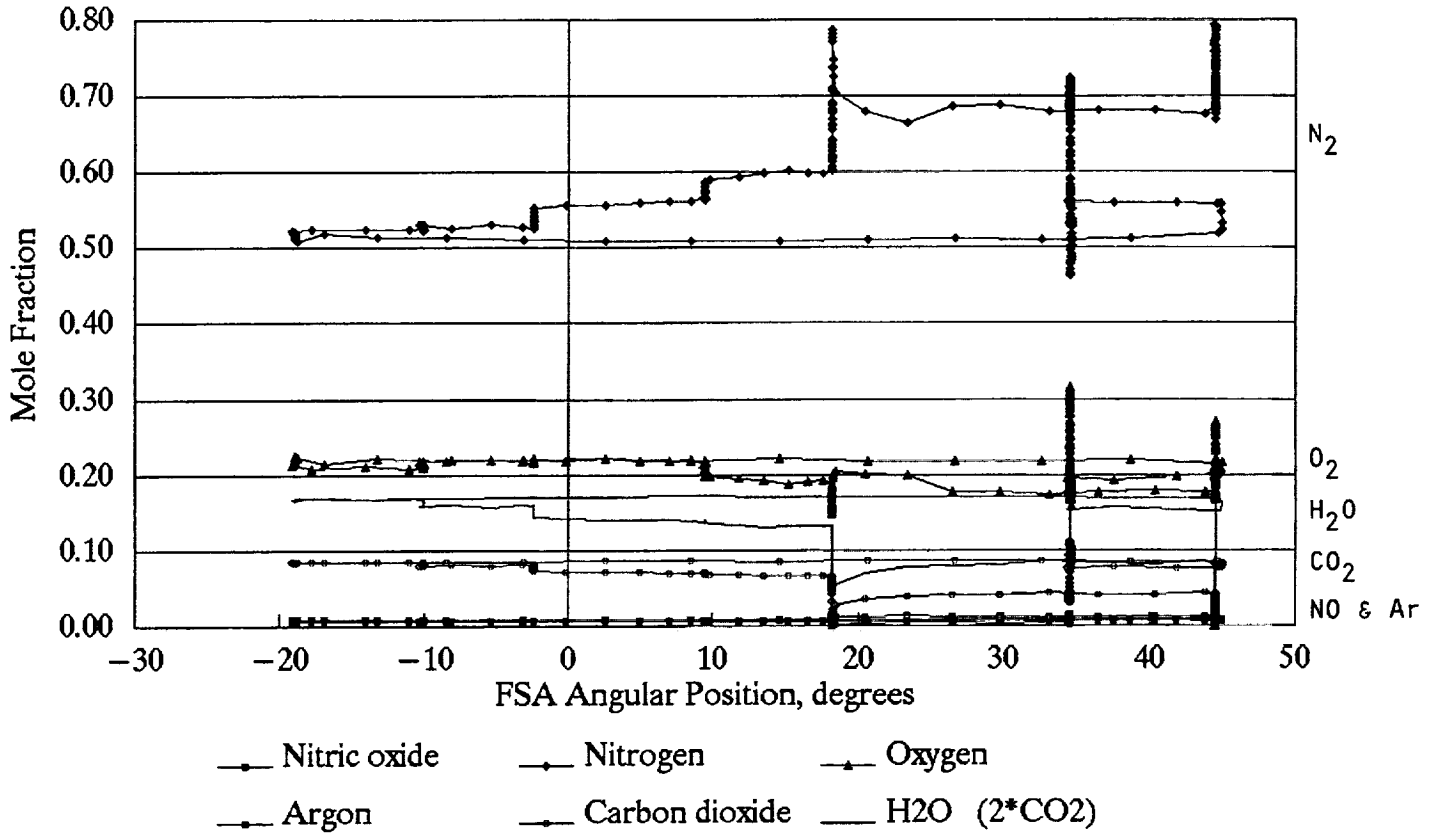
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.529	+/-	0.035
Oxygen:	0.210	+/-	0.026
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.012
H ₂ O:	0.162	+/-	0.023
Nitric oxide:	0.010	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions vs. FSA Position

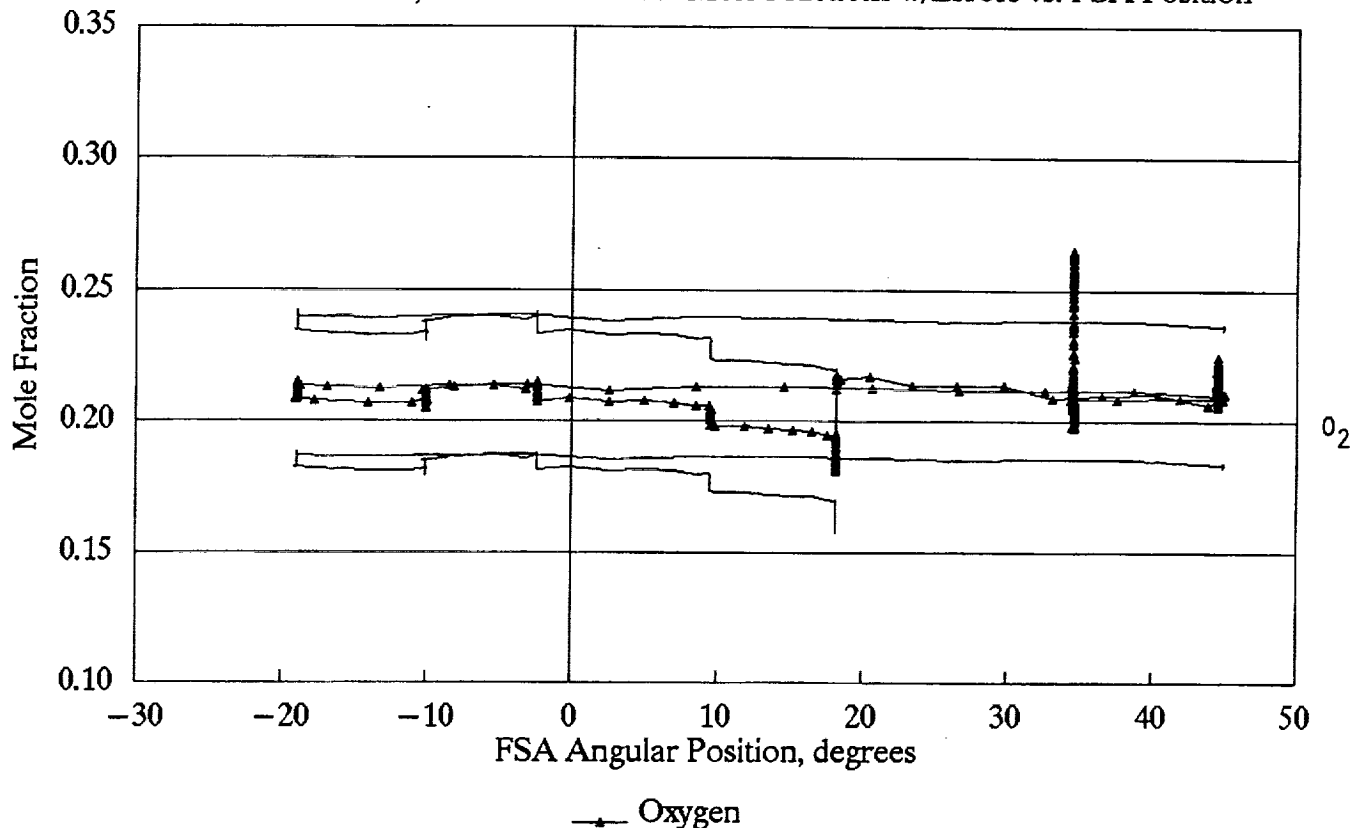


CO2 fragmentation coefficient: 0.0817.
Mole Fractions, averaged from 135 to 145 seconds:

Nitrogen:	0.530	+/-	0.052
Oxygen:	0.216	+/-	0.031
Argon:	0.006	+/-	0.001
Carbon dioxide:	0.080	+/-	0.014
H2O:	0.160	+/-	0.024
Nitric oxide:	0.007	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

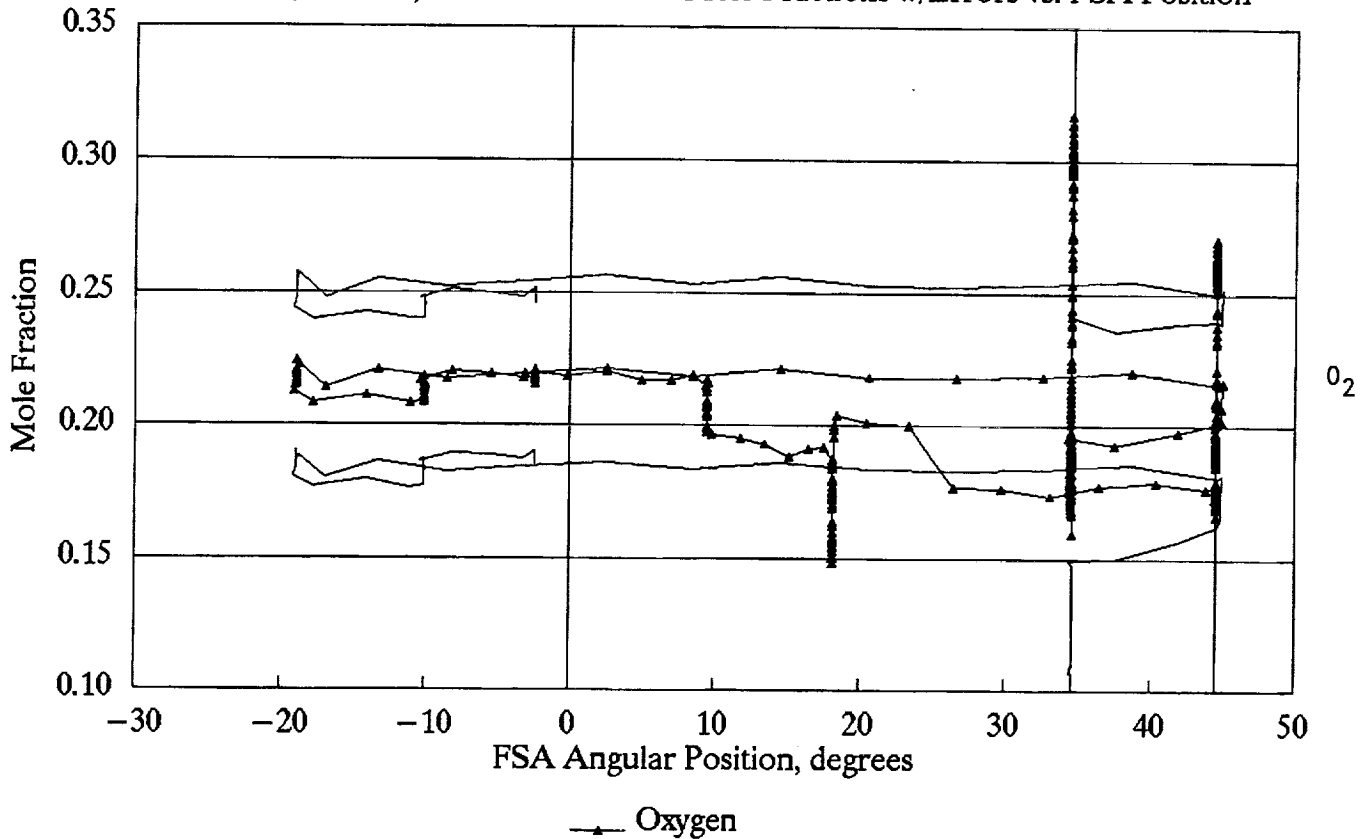
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.210 +/- 0.026

8' HTT Gas Analysis System

Test 13 9 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

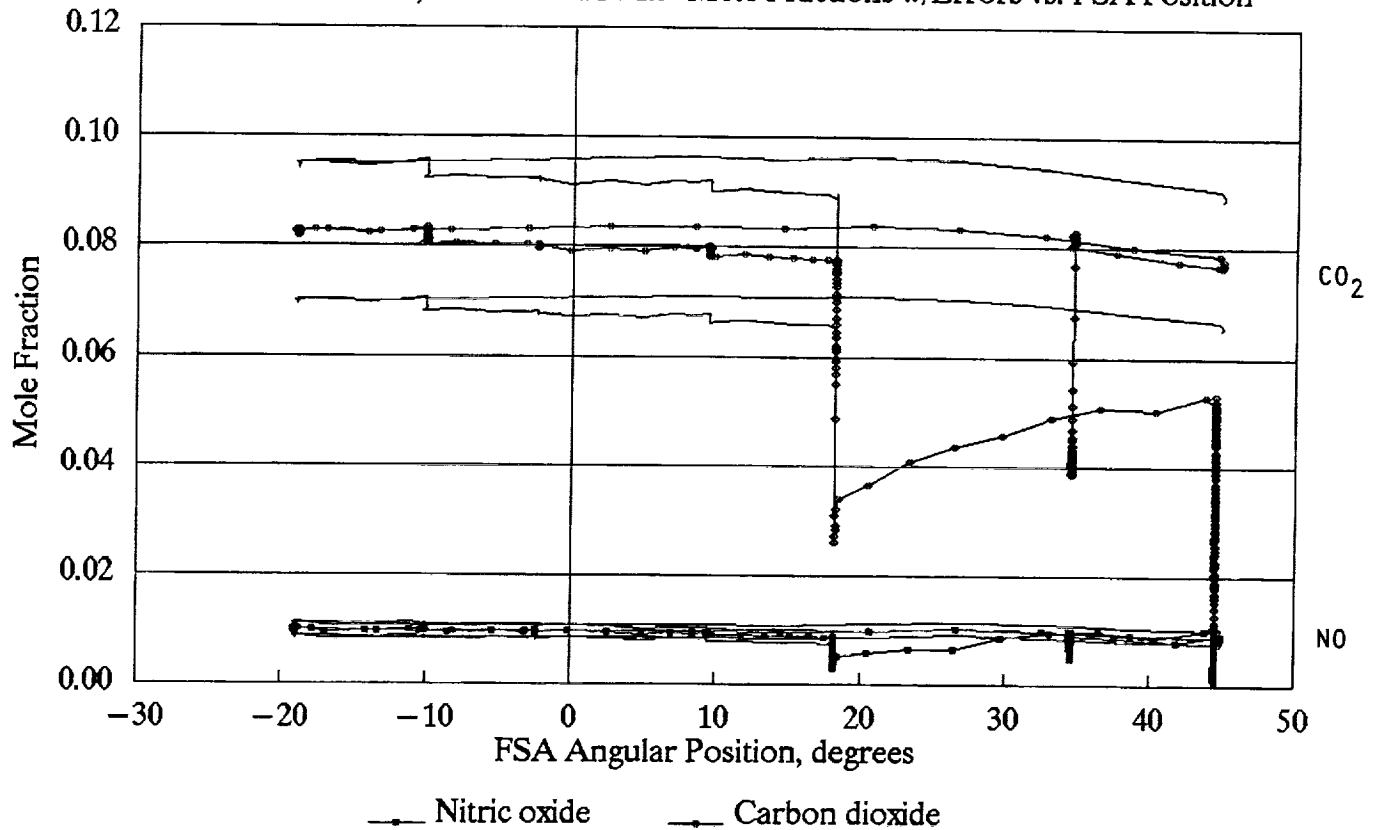
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Oxygen: 0.216 +/- 0.031

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

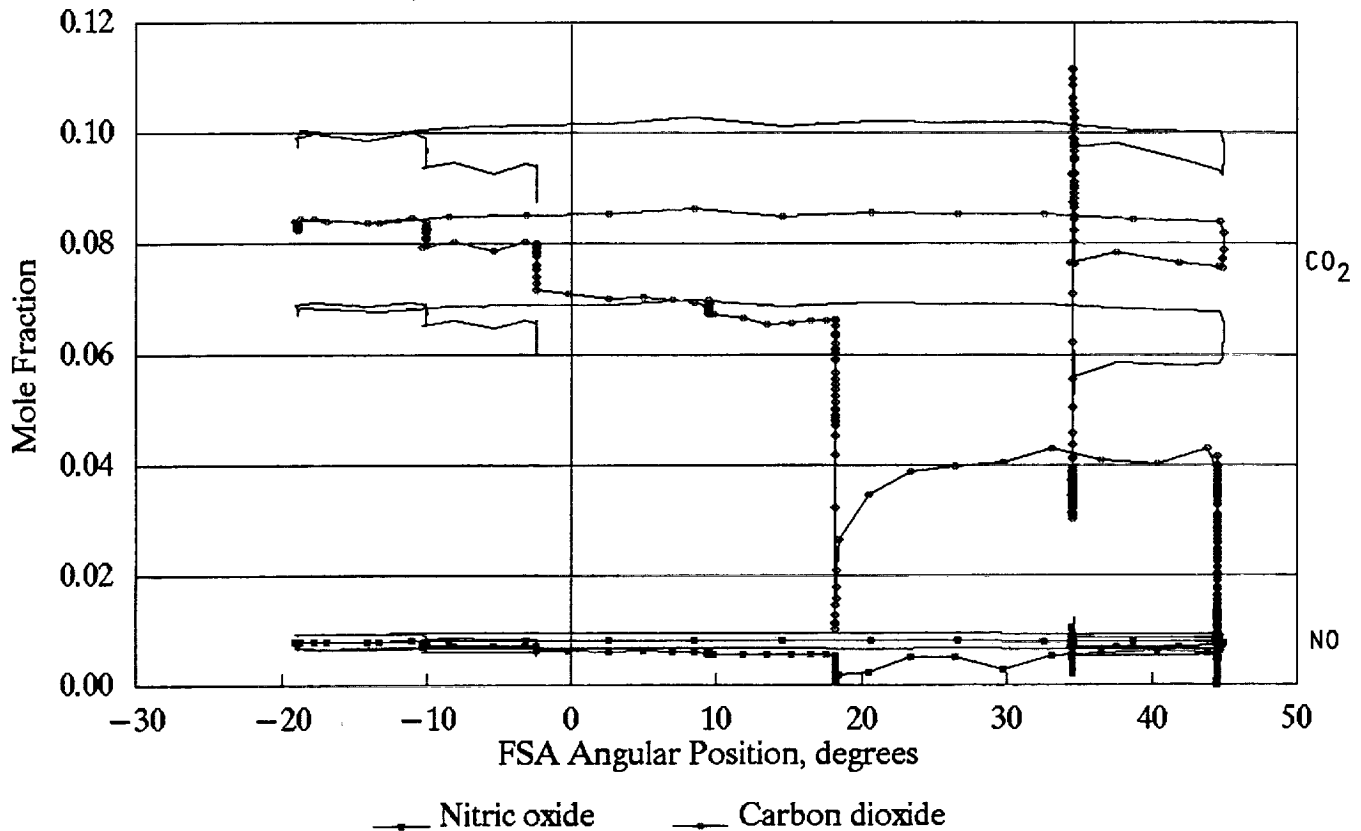
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.081	+/-	0.012
Nitric oxide:	0.010	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

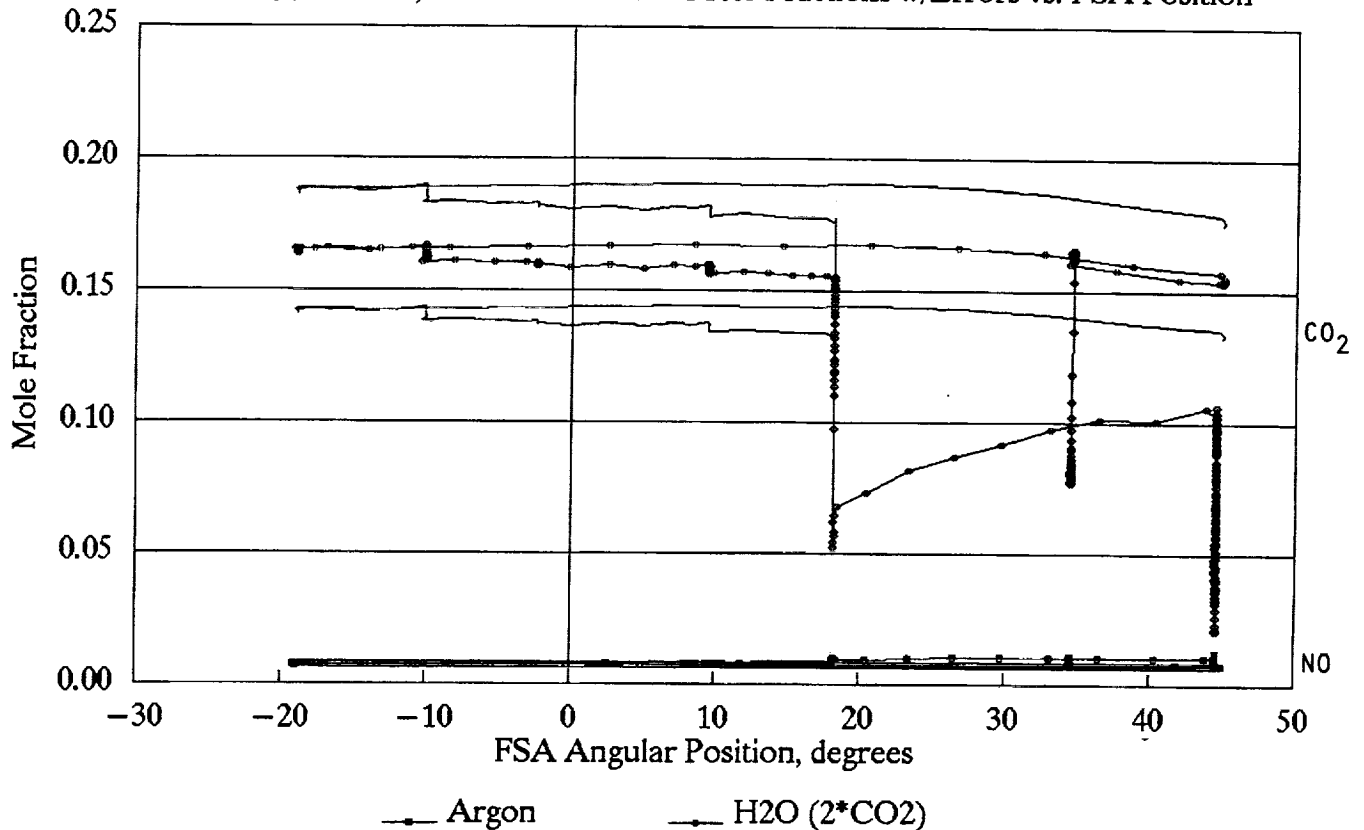
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Carbon dioxide:	0.080	+/-	0.014
Nitric oxide:	0.007	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 12, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

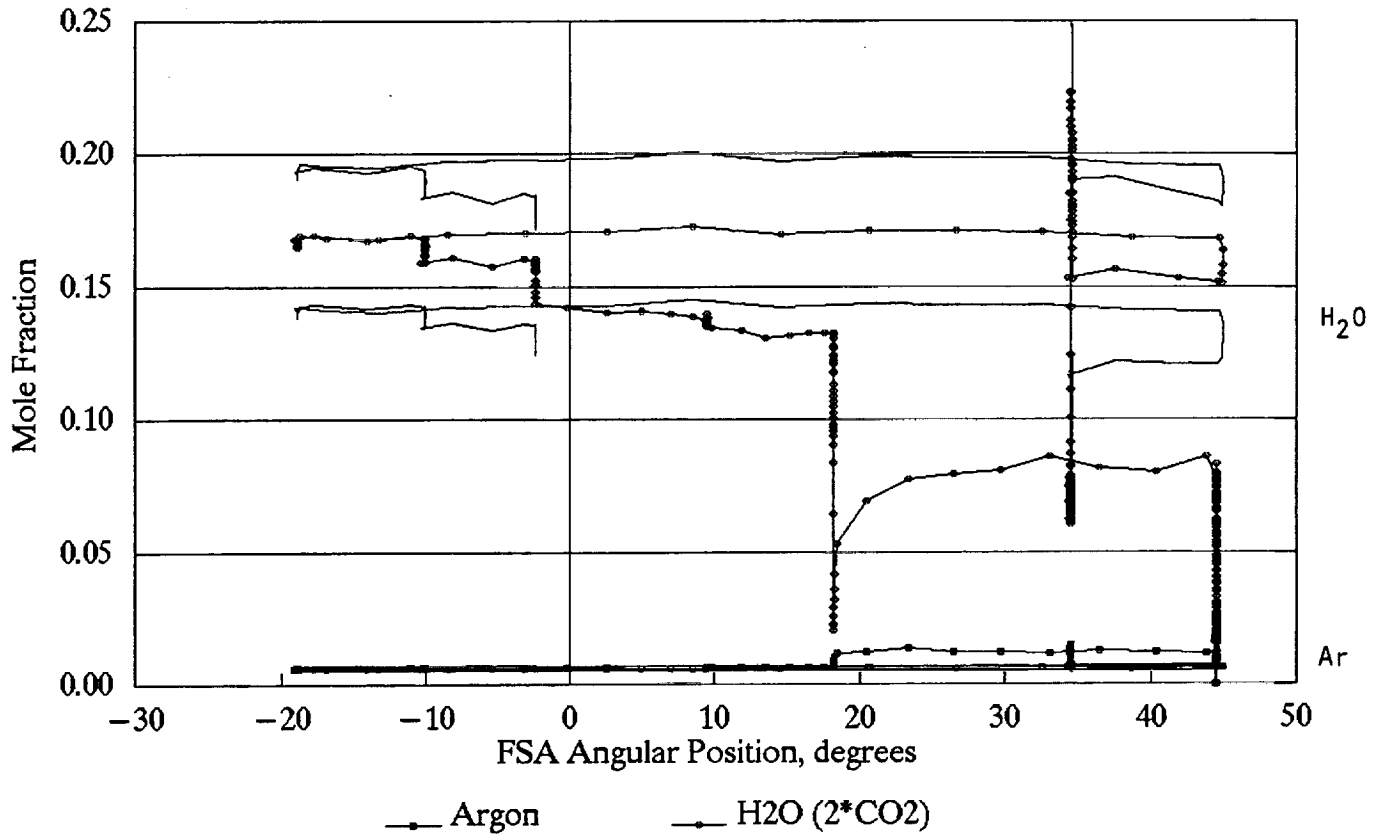
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.023

8' HTT Gas Analysis System

Test 139 Run 12, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 135 to 145 seconds:

Argon:	0.006	+/-	0.001
H2O:	0.160	+/-	0.024

Test 139 Run 15

Combustor Pressure: 1560 psia

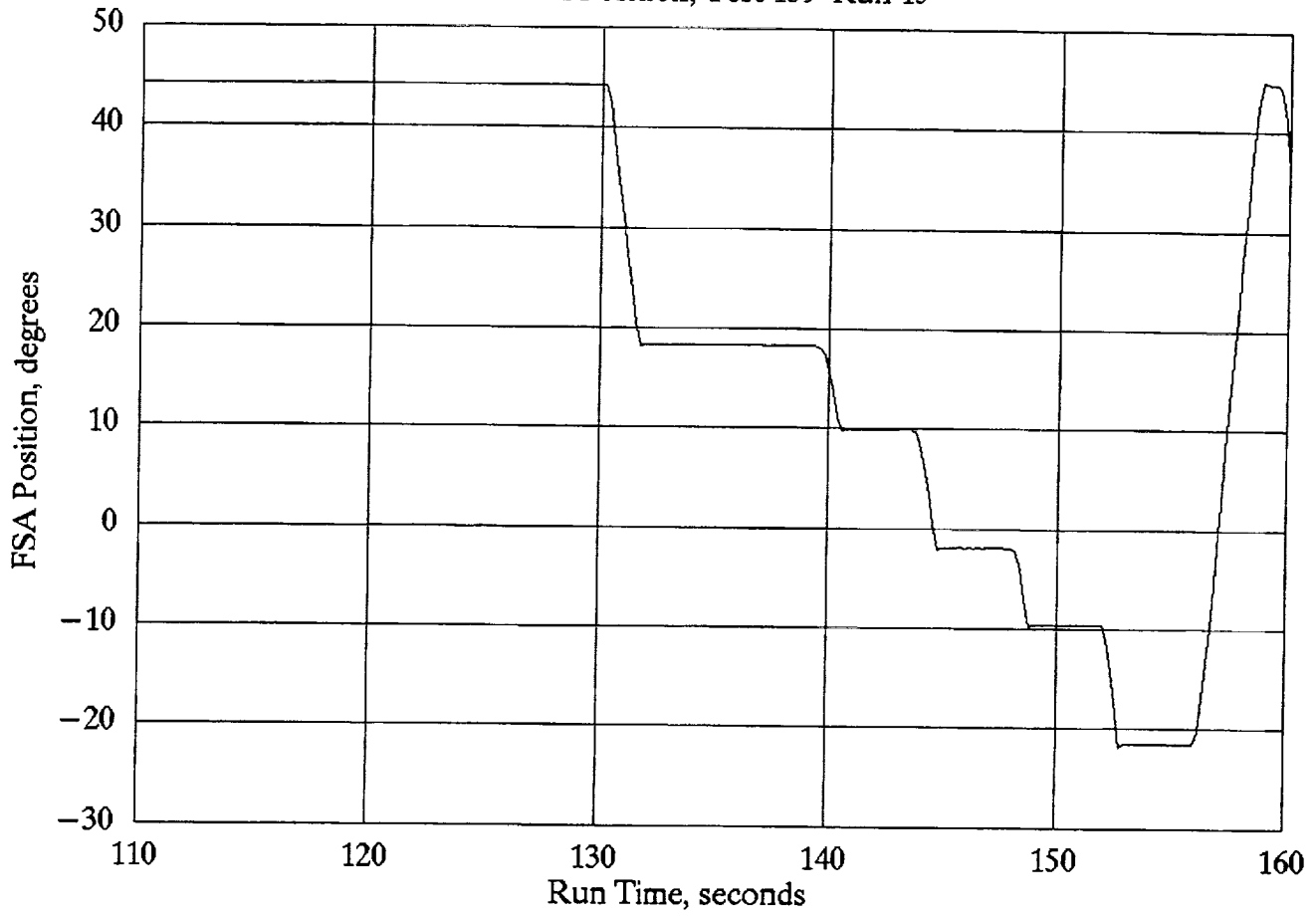
Combustor Temperature: 3400 R

Normal Stop: 157.0 seconds

Probes: FSA+1.5, FSA-1.5

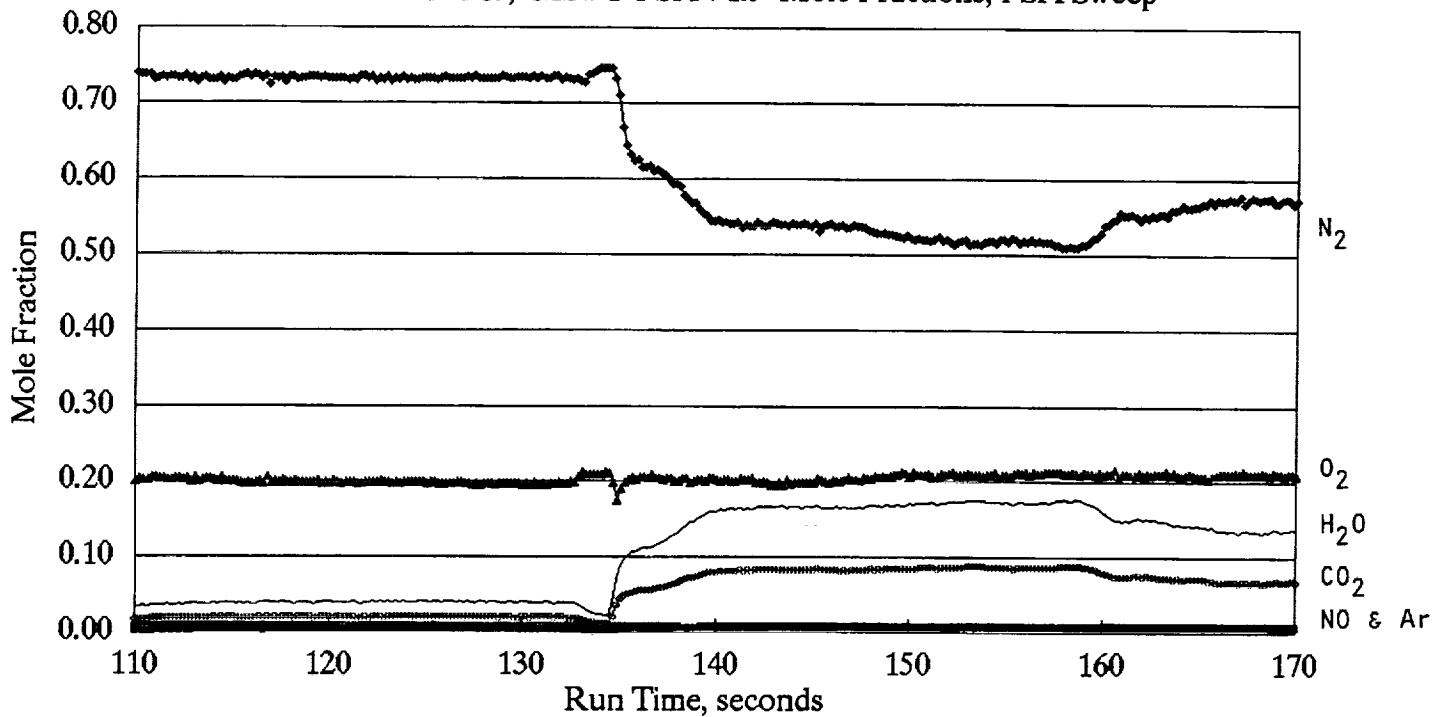
8' HTT Gas Analysis System

FSA Position, Test 139 Run 15



8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA +1.5 Mole Fractions, FSA Sweep



Sum of mole fractions = 1.

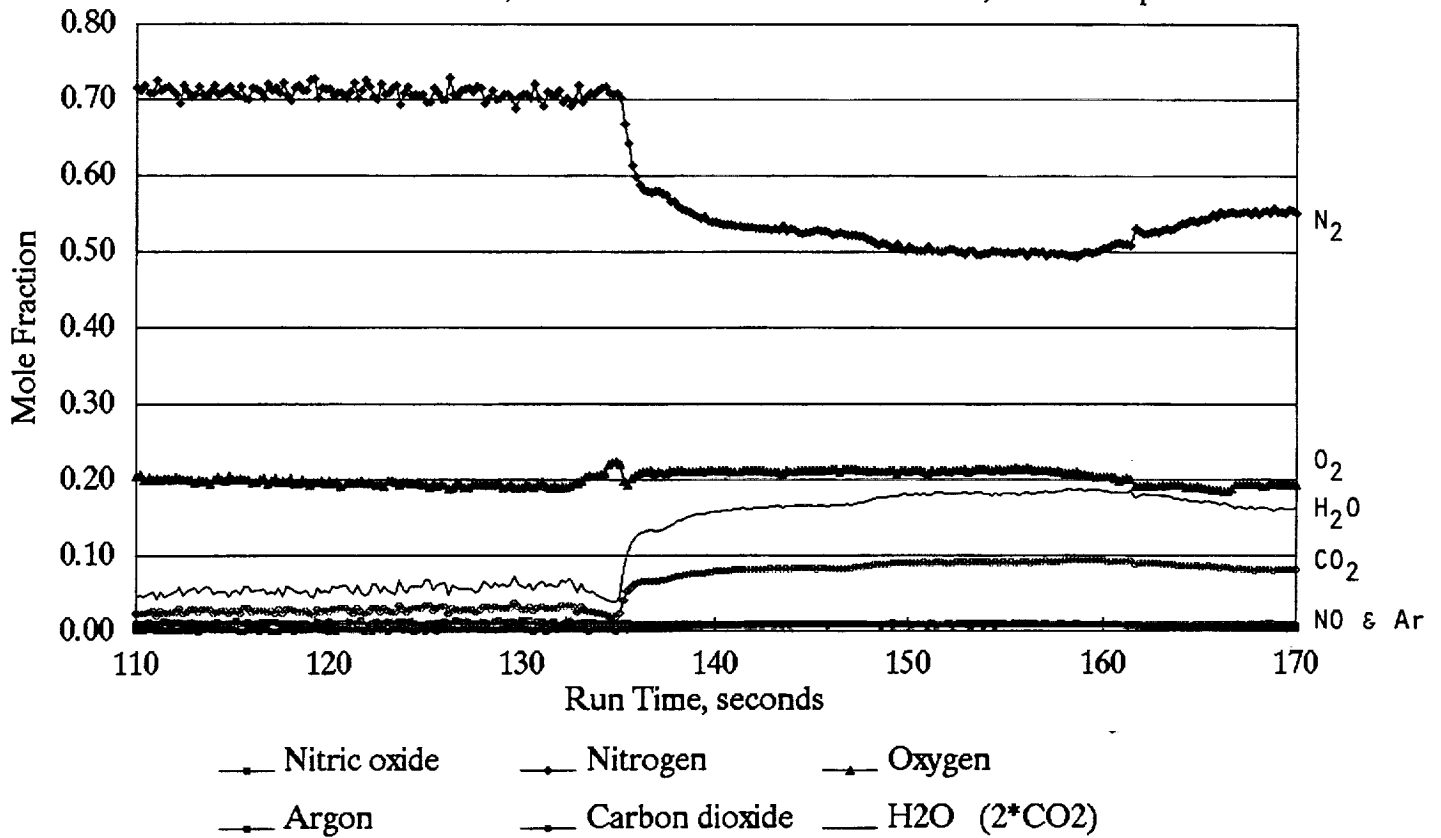
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen:	0.531	+/-	0.019
Oxygen:	0.203	+/-	0.014
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.084	+/-	0.009
H2O:	0.167	+/-	0.017
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions, FSA Sweep



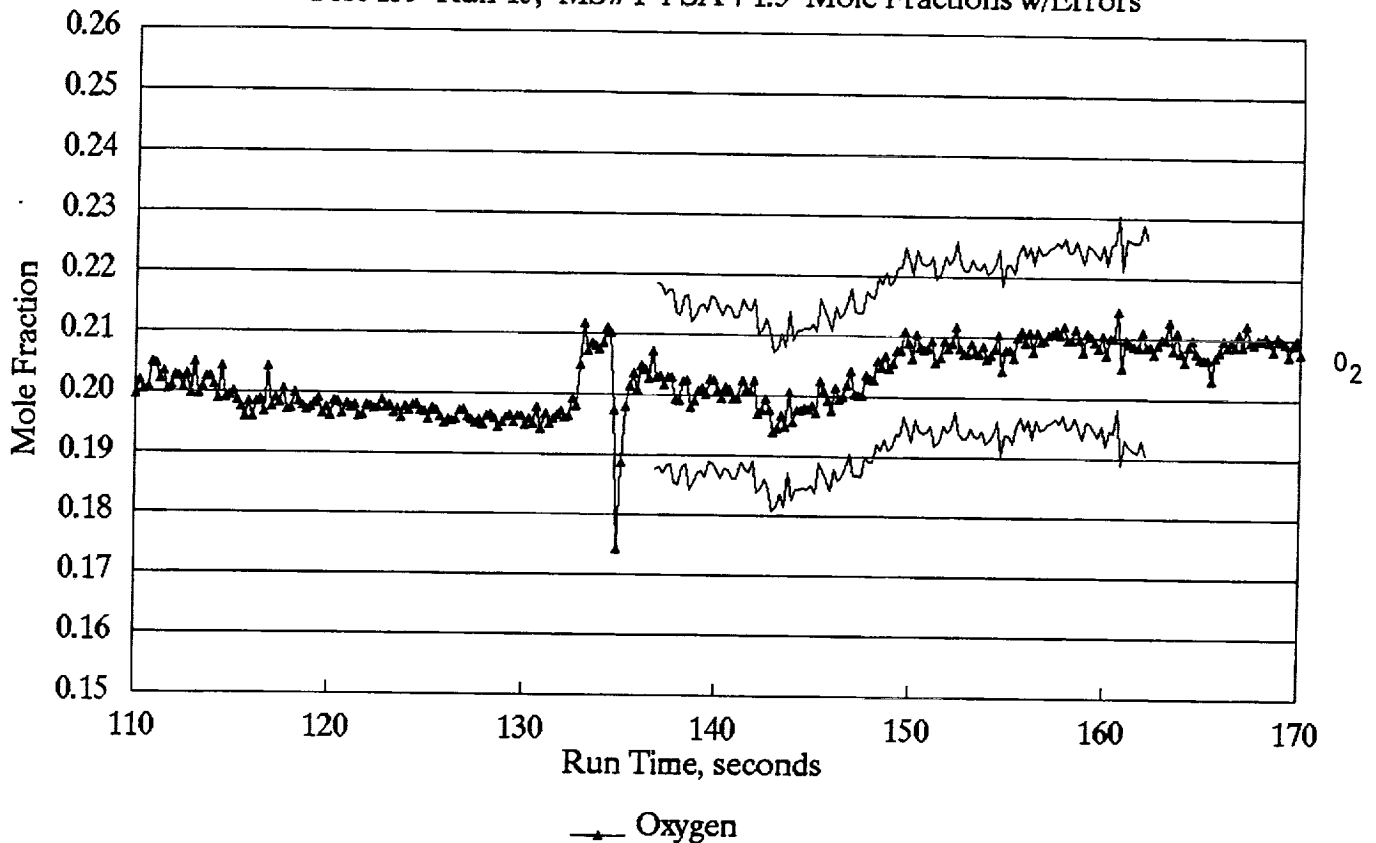
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen:	0.517	+/-	0.030
Oxygen:	0.211	+/-	0.020
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.086	+/-	0.011
H2O:	0.171	+/-	0.020
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

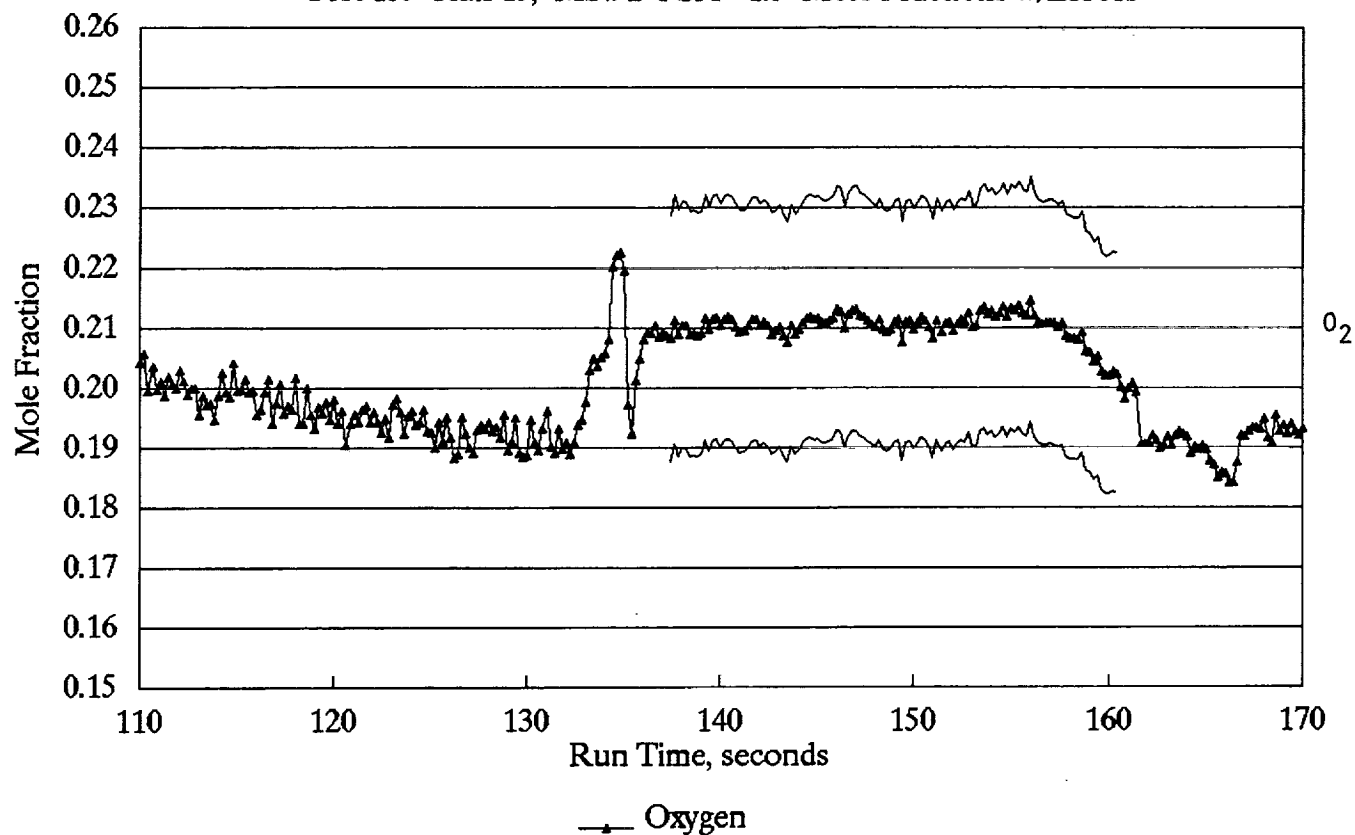
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Oxygen: 0.203 +/- 0.014

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

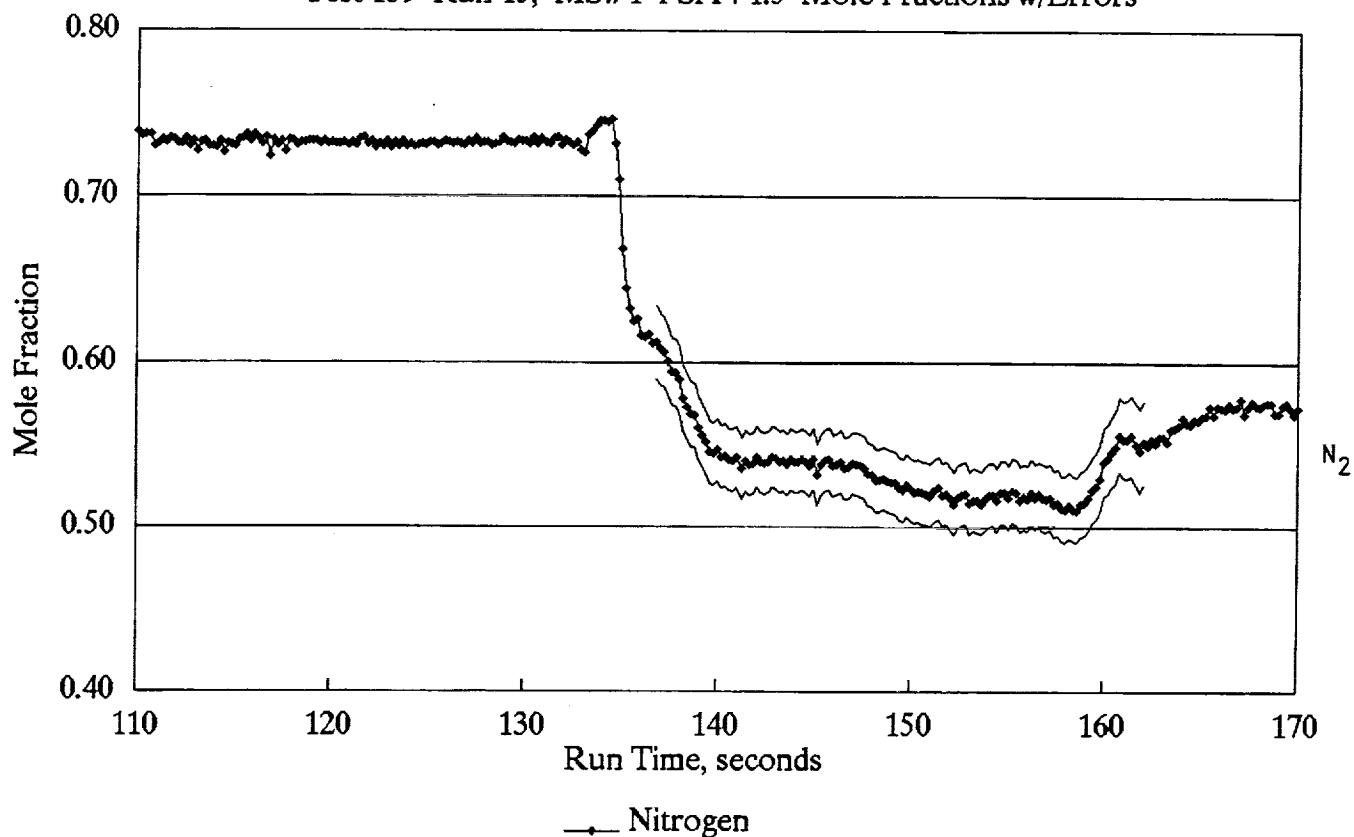
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Oxygen: 0.211 +/- 0.020

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

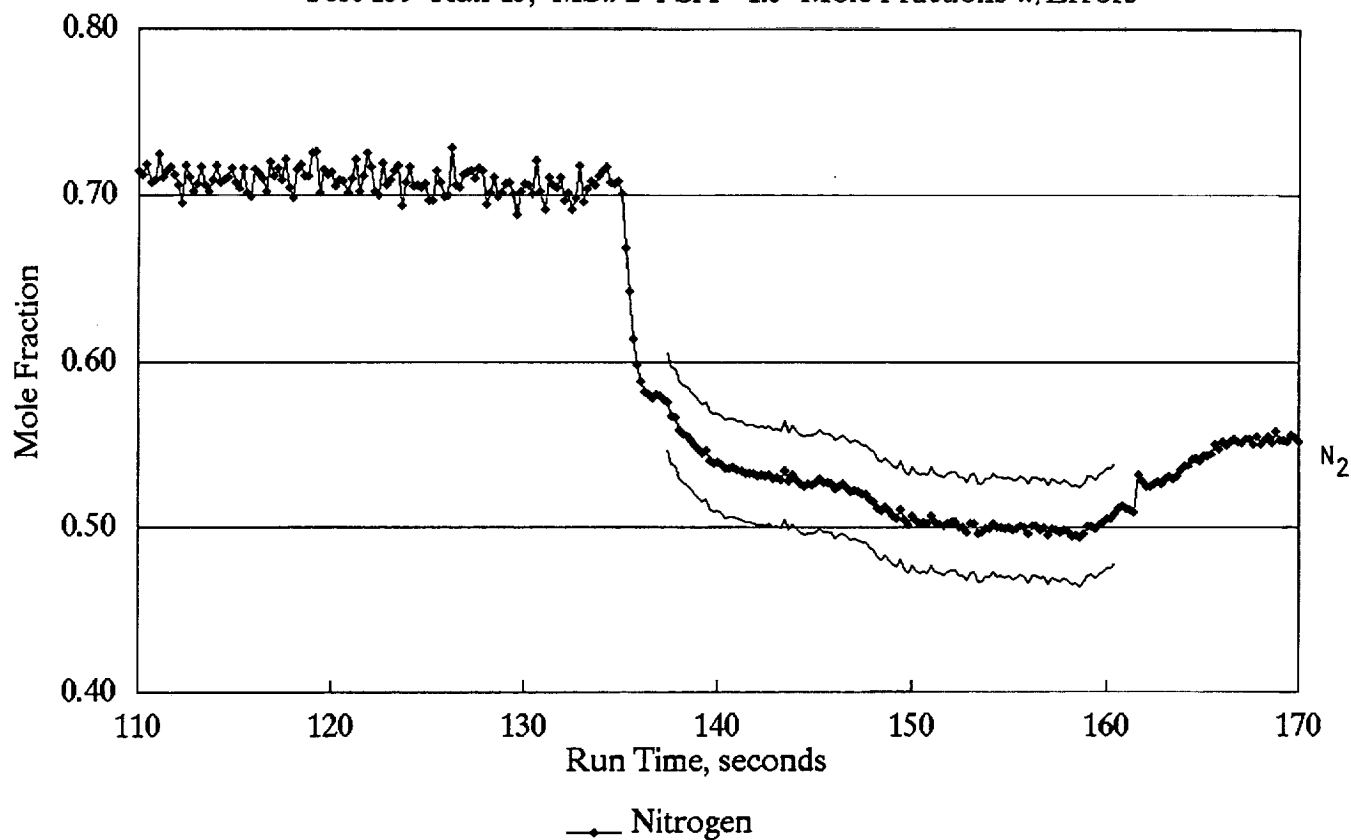
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen: 0.531 +/- 0.019

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

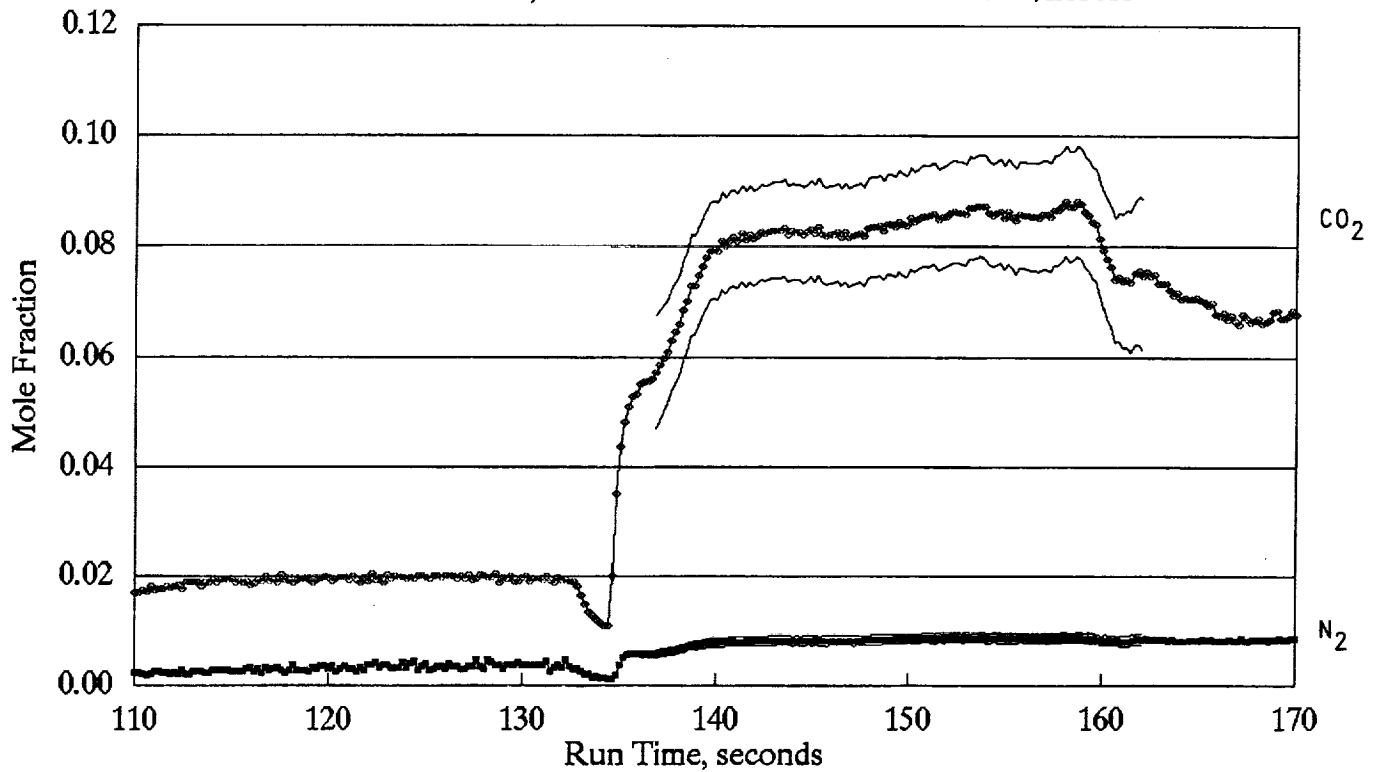
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen: 0.517 +/- 0.030

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

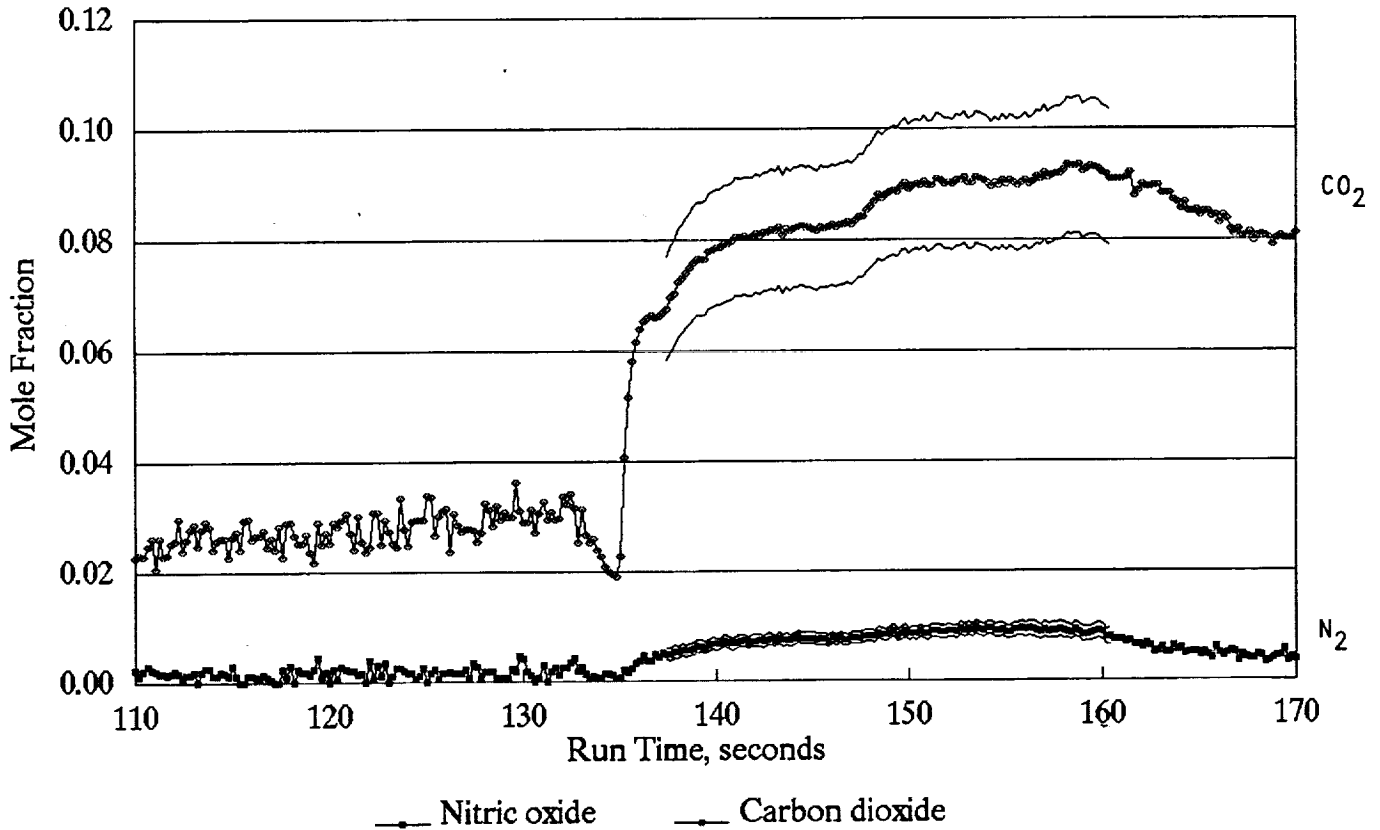
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Carbon dioxide:	0.084	+/-	0.009
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

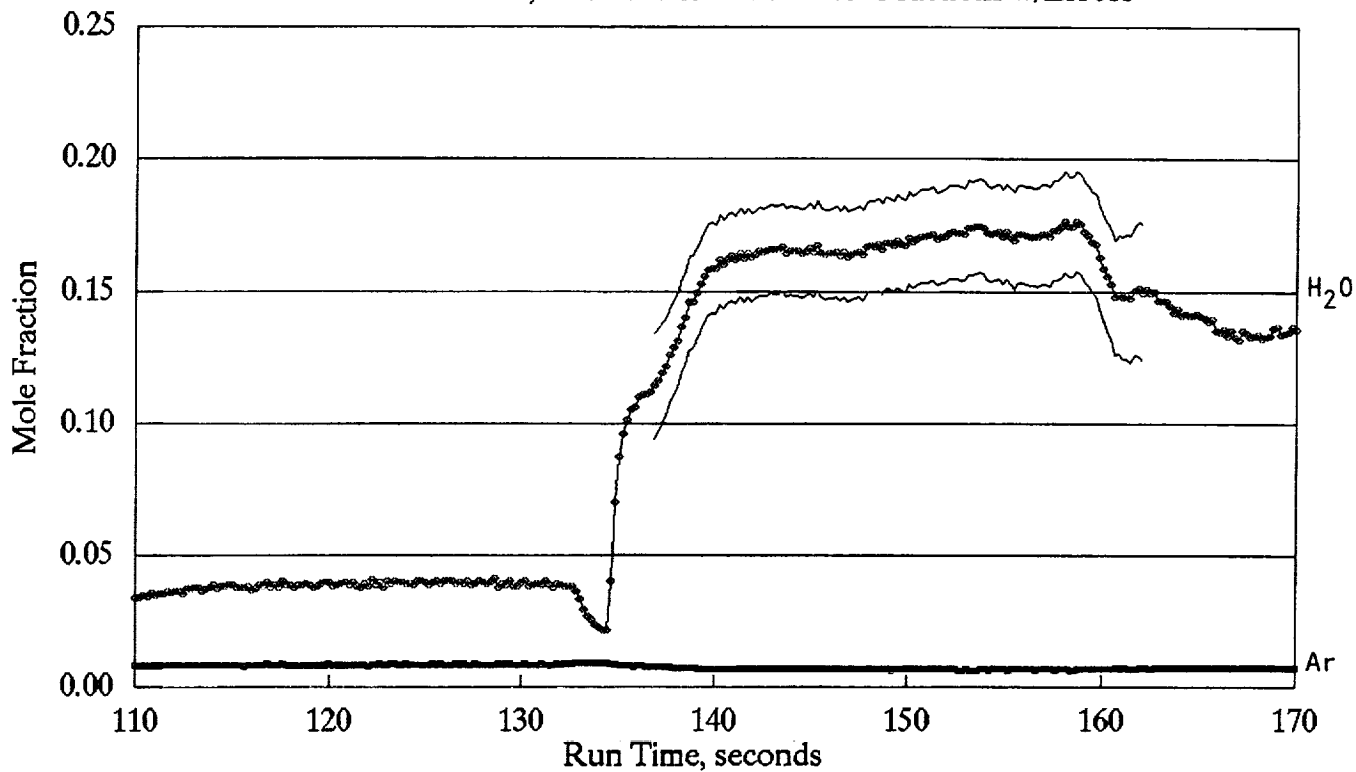
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Carbon dioxide:	0.086	+/-	0.011
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors



— Argon — H₂O (2*CO₂)

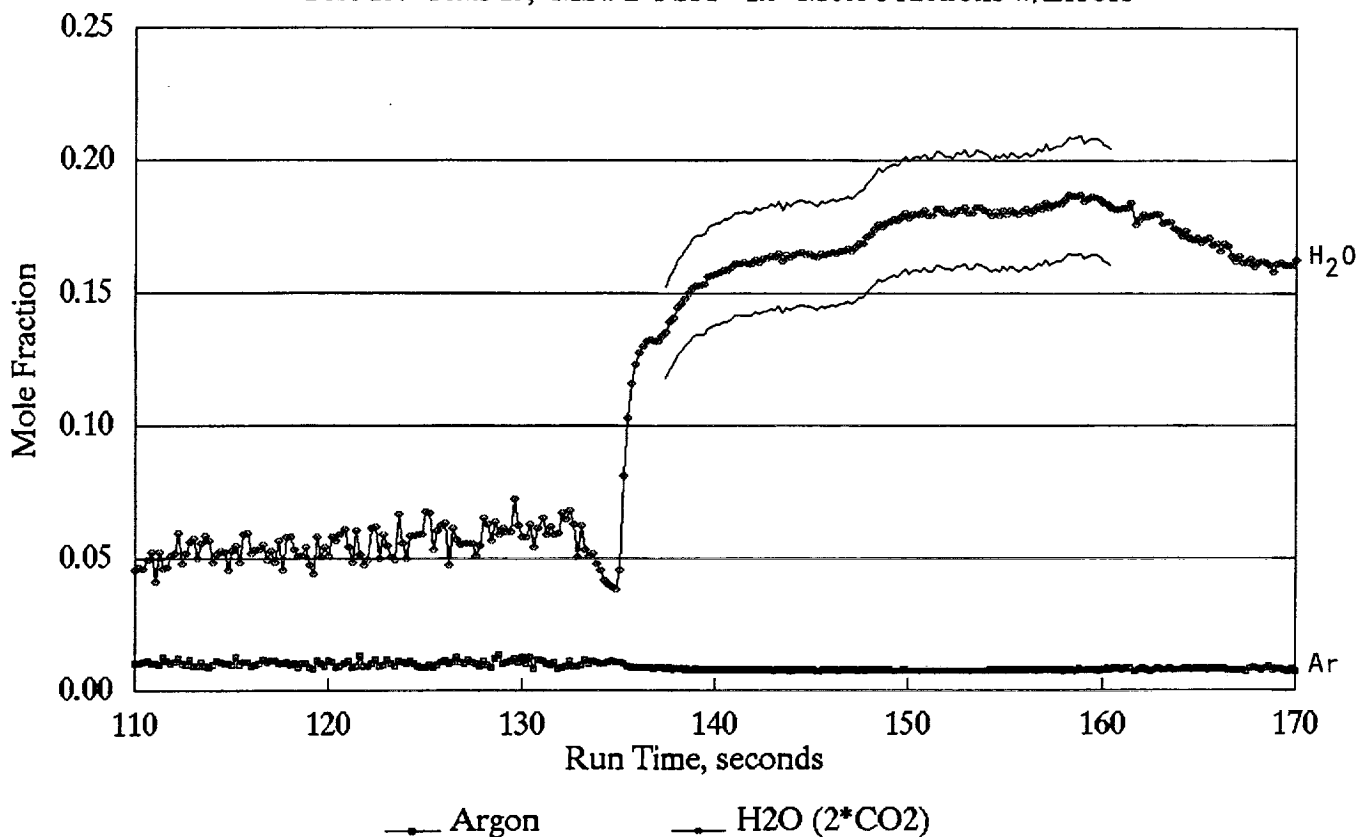
Errors given at 95% level of confidence.

CO₂ fragmentation coefficient: 0.0817.
Mole Fractions, averaged from 140 to 155 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.167	+/-	0.017

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

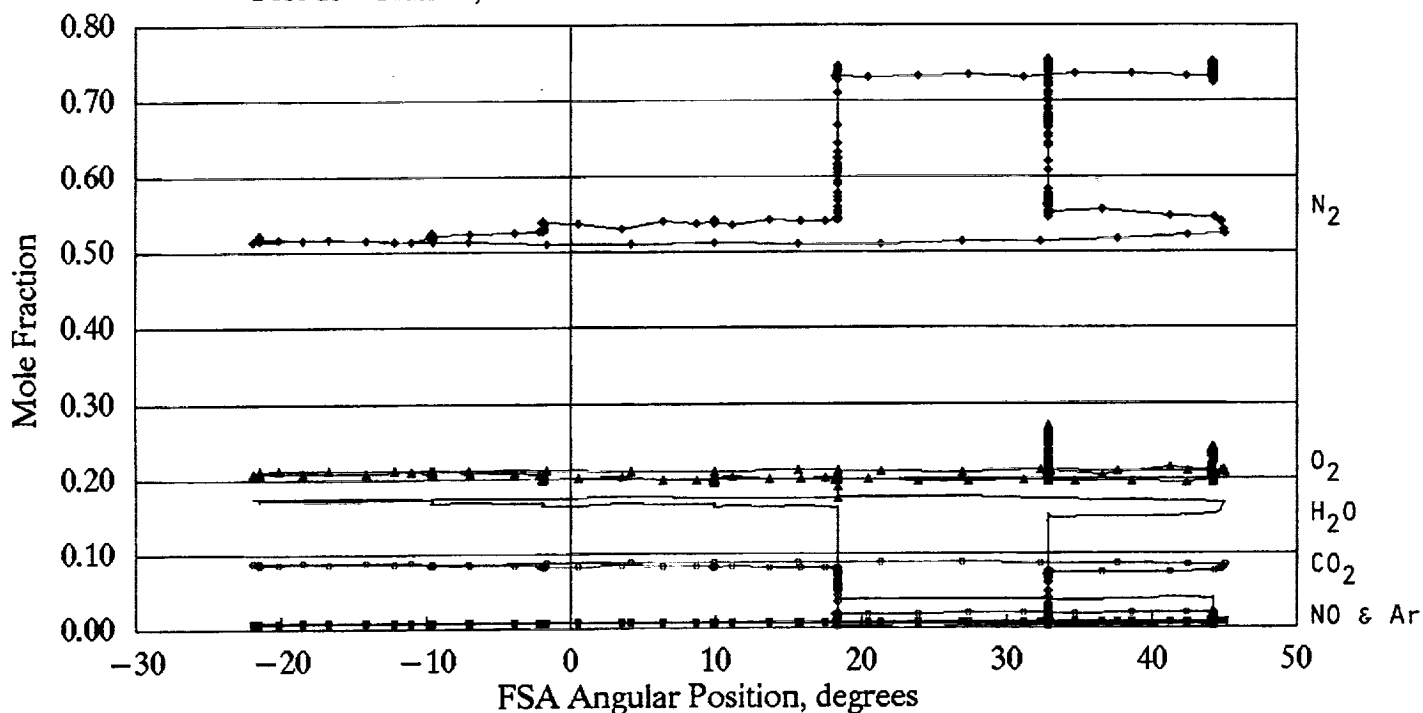
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.171	+/-	0.020

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



—•— Nitric oxide —•— Nitrogen —▲— Oxygen
 —■— Argon —●— Carbon dioxide — H2O (2*CO2)

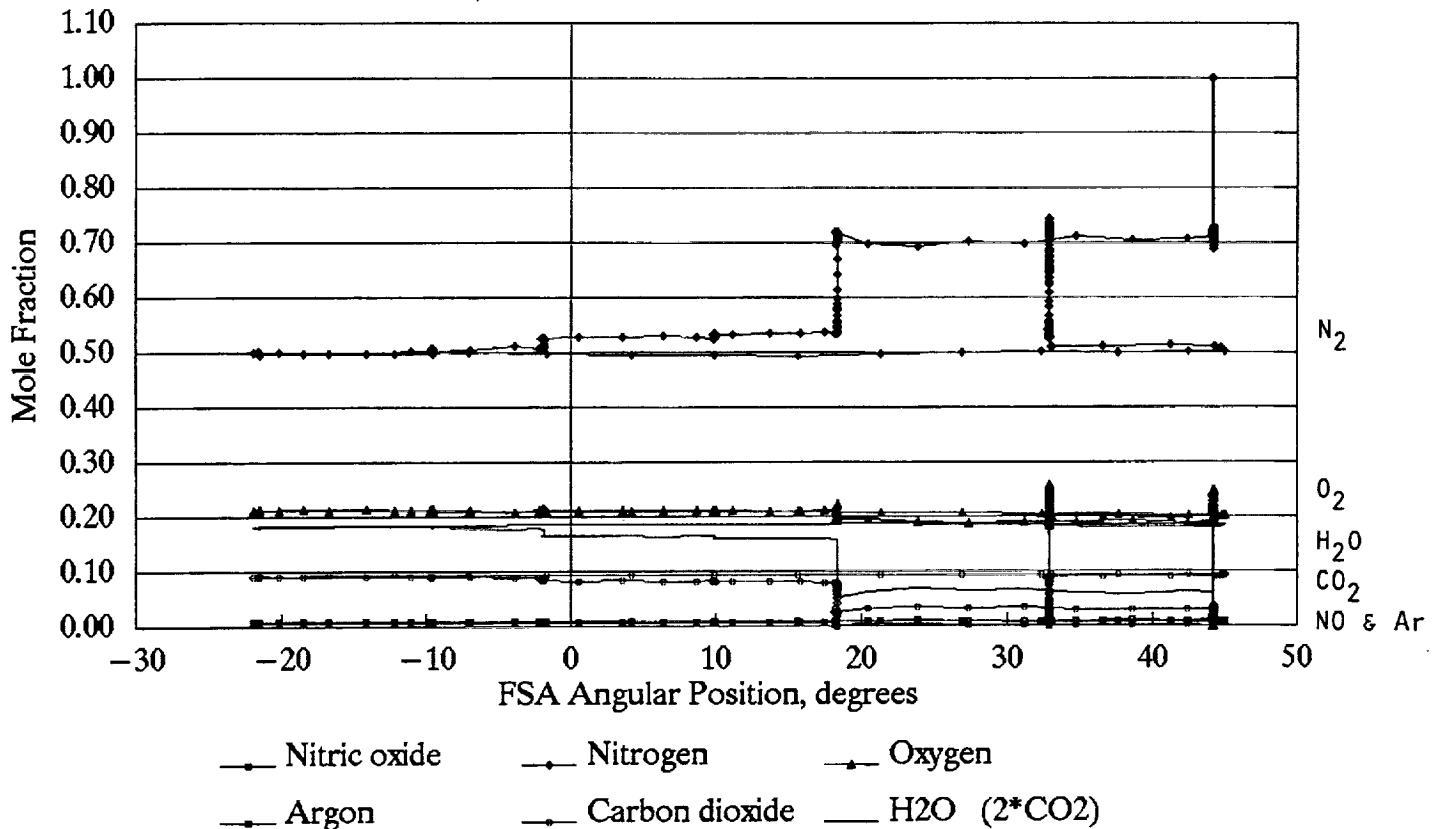
Sum of mole fractions = 1.

CO2 fragmentation coefficient: 0.0817.
 Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen:	0.531	+/-	0.019
Oxygen:	0.203	+/-	0.014
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.084	+/-	0.009
H2O:	0.167	+/-	0.017
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions vs. FSA Position



Sum of mole fractions = 1.

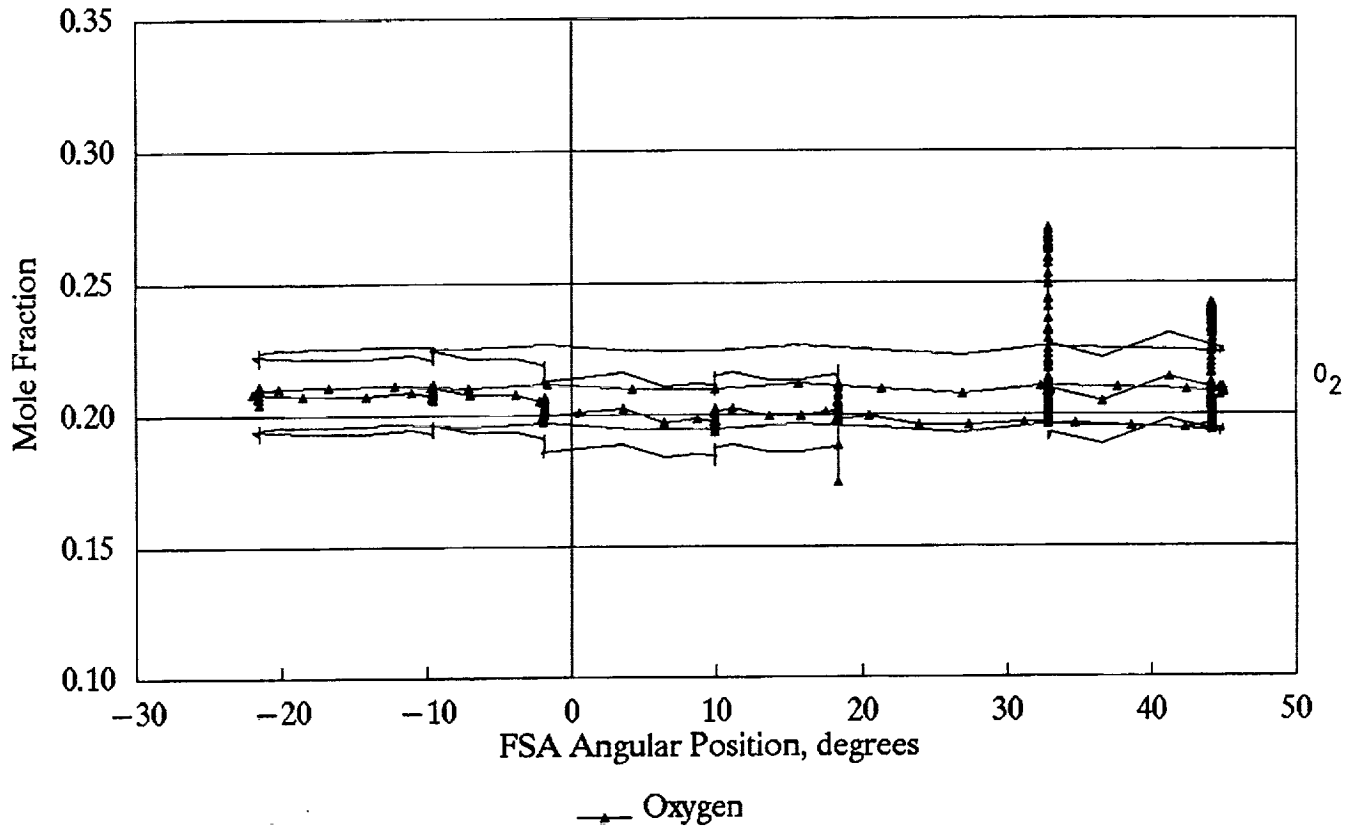
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Nitrogen:	0.517	+/-	0.030
Oxygen:	0.211	+/-	0.020
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.086	+/-	0.011
H2O:	0.171	+/-	0.020
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 13⁹ Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

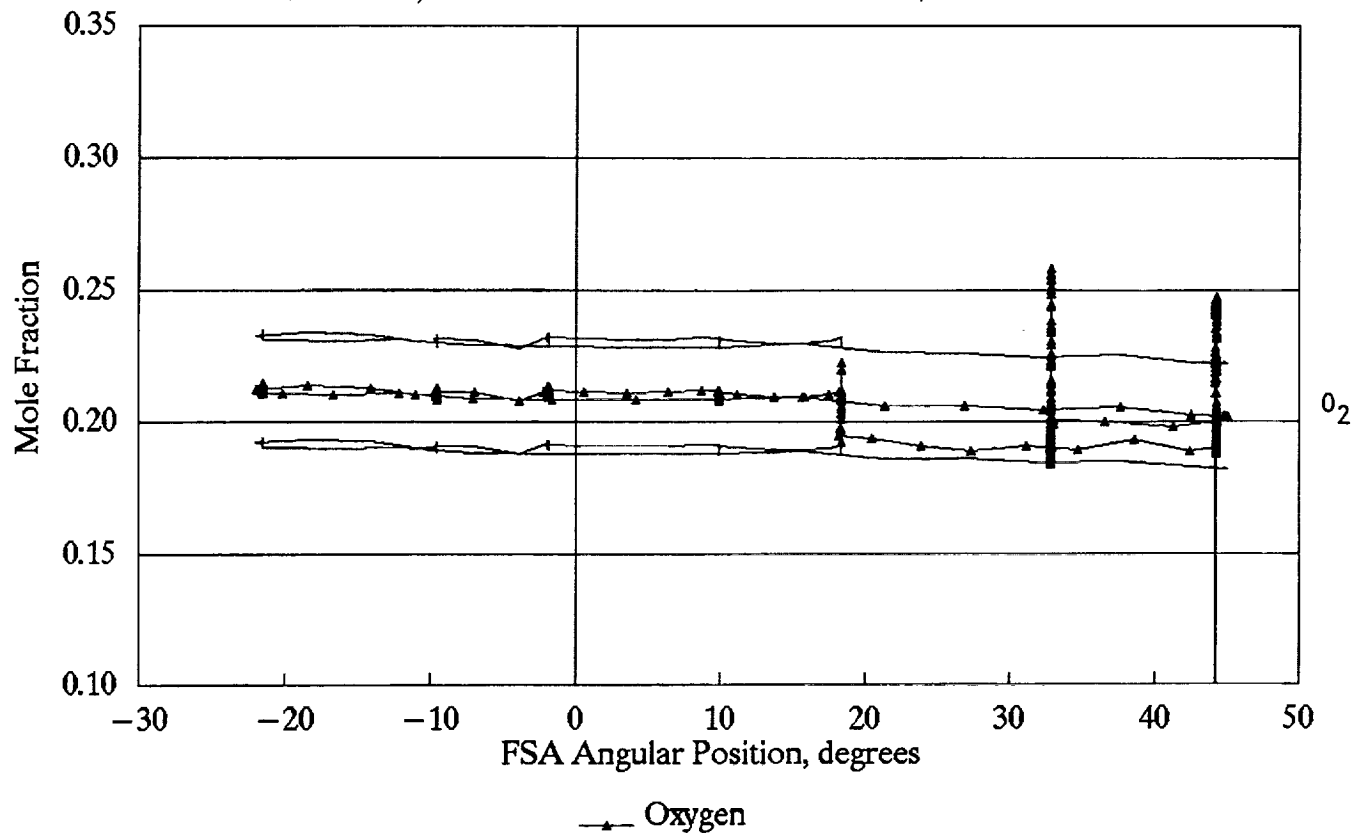
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Oxygen: 0.203 +/- 0.014

8' HTT Gas Analysis System

Test 13.9 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

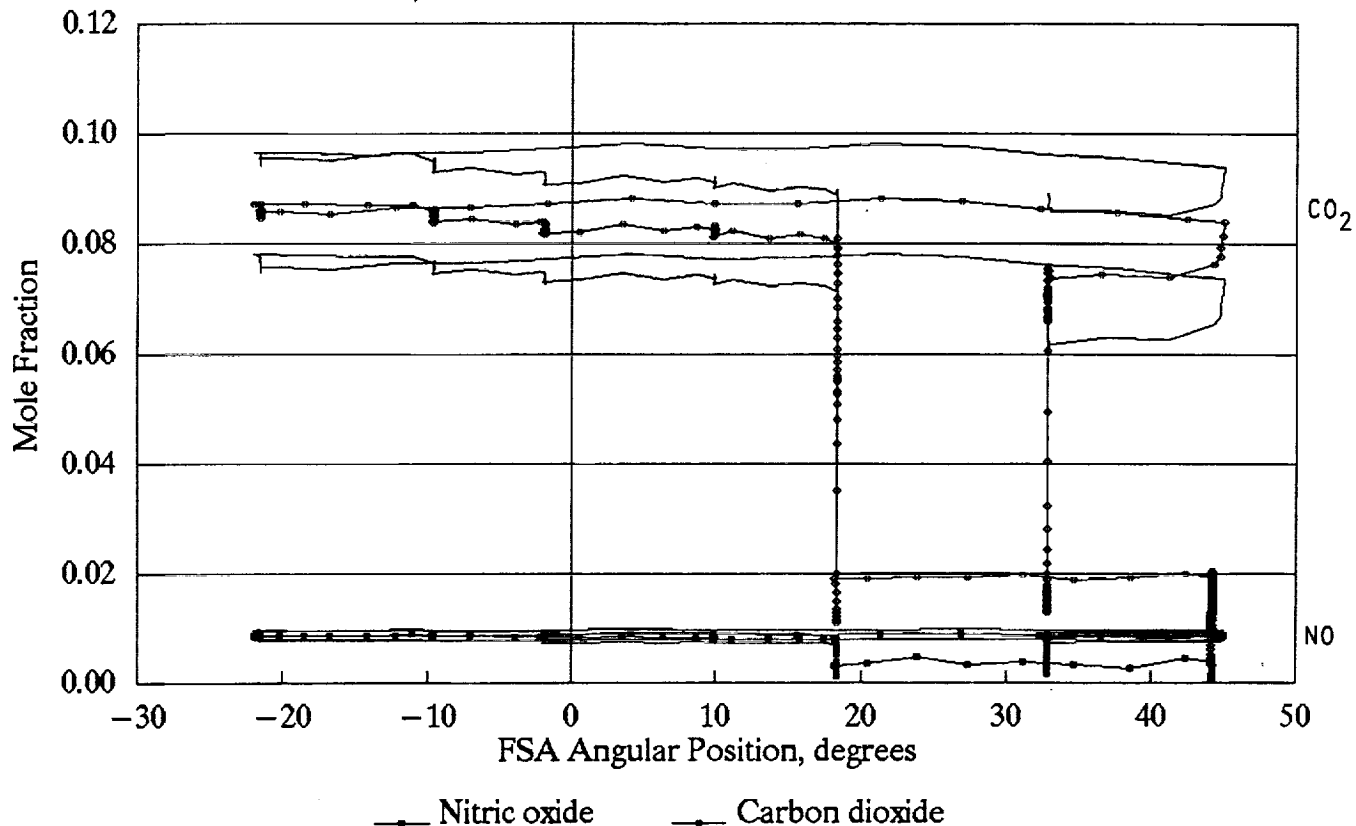
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Oxygen: 0.211 +/- 0.020

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

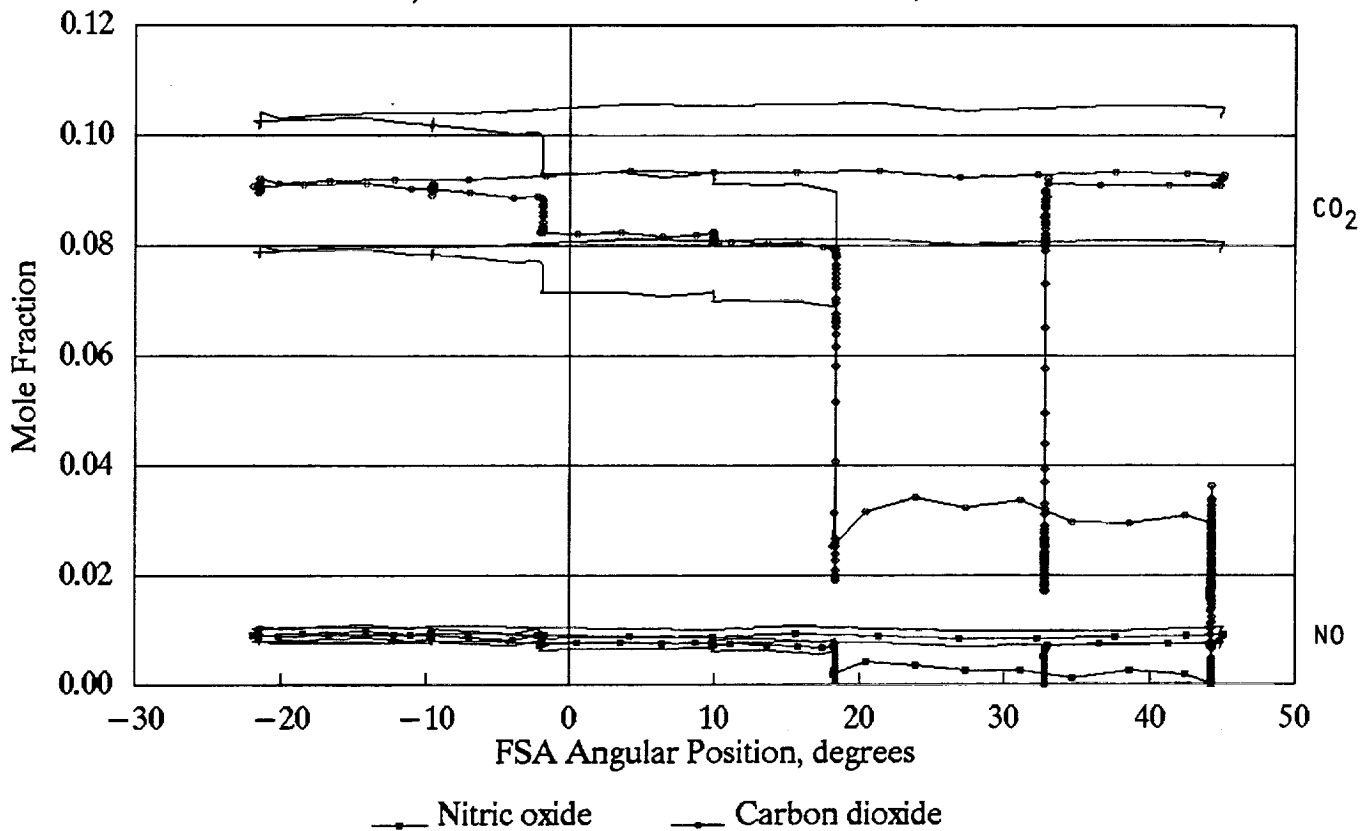
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Carbon dioxide:	0.084	+/-	0.009
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

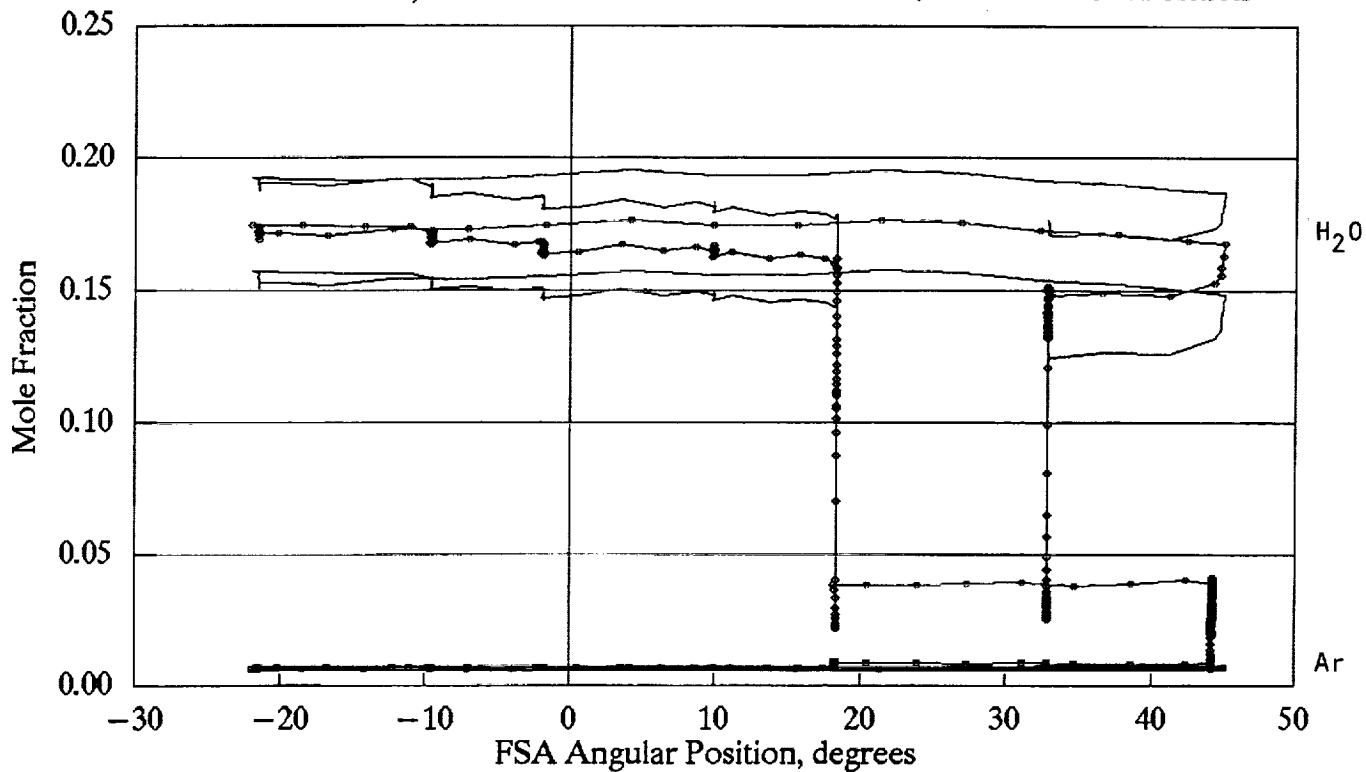
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Carbon dioxide:	0.086	+/-	0.011
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 15, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



— Argon

— H₂O (2*CO₂)

Errors given at 95% level of confidence.

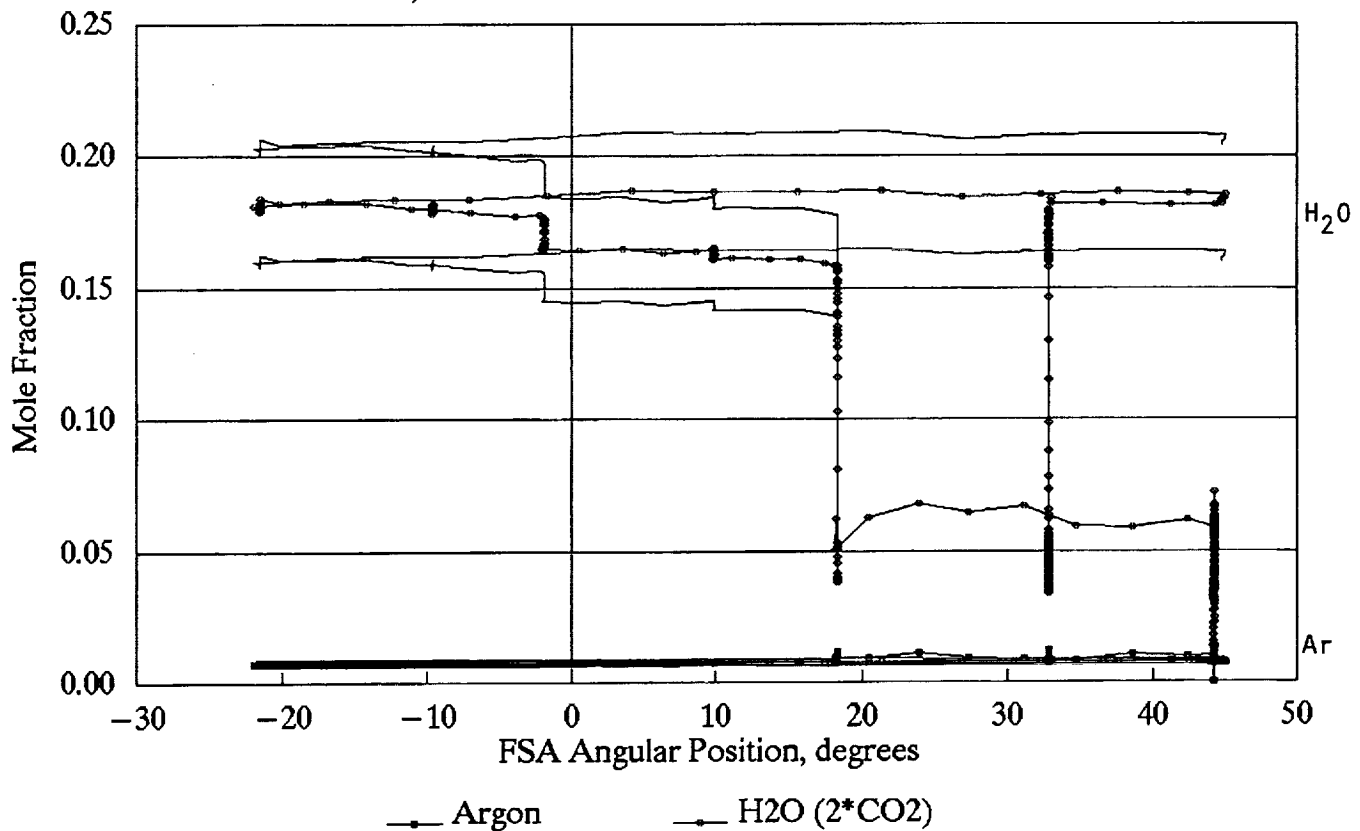
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.167	+/-	0.017

8' HTT Gas Analysis System

Test 139 Run 15, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 155 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.171	+/-	0.020

Test 139 Run 16

Combustor Pressure: 1560 psia

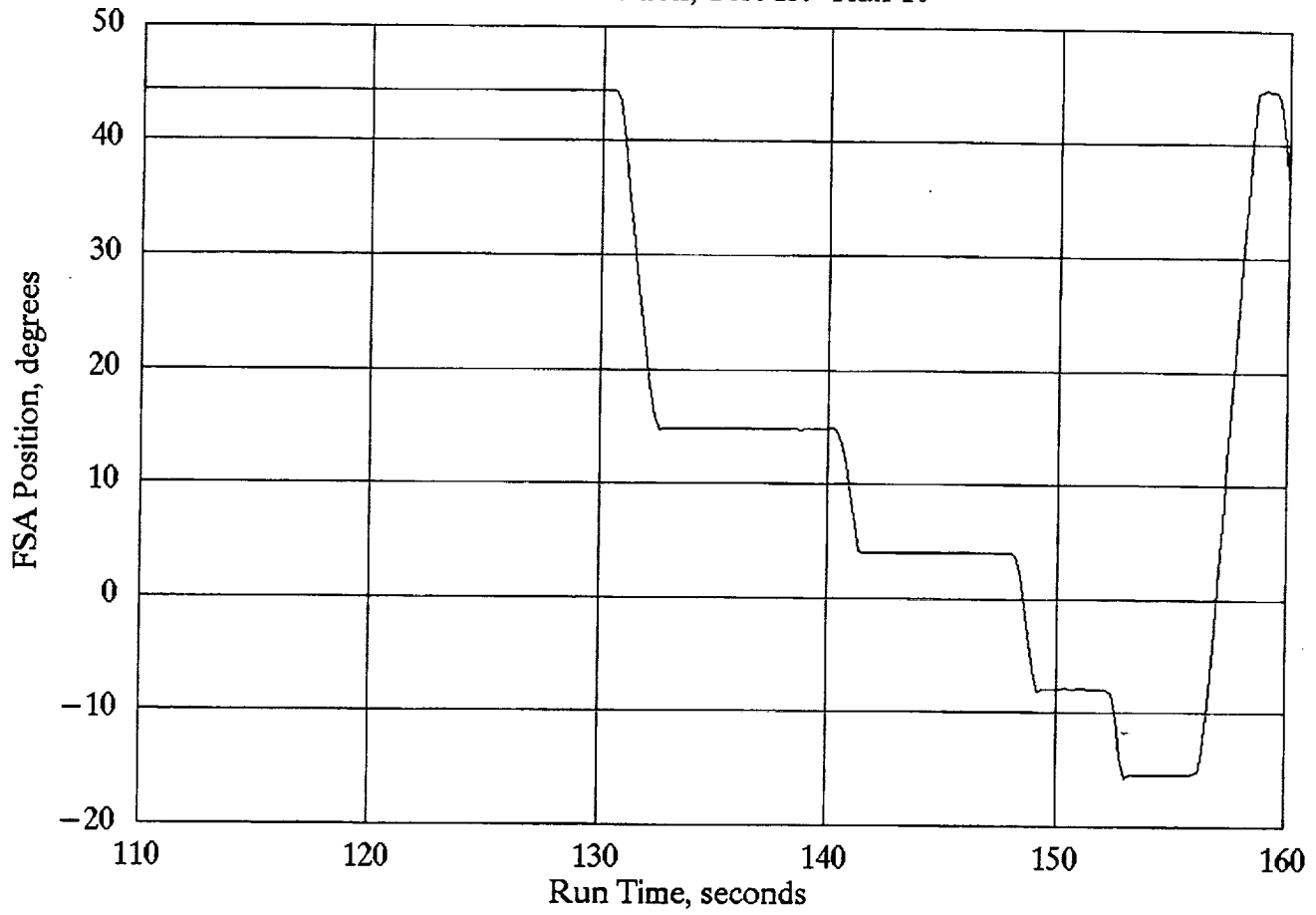
Combustor Temperature: 3400 R

Normal Stop: 161.2 seconds

Probes: FSA+7.5, FSA+1.5

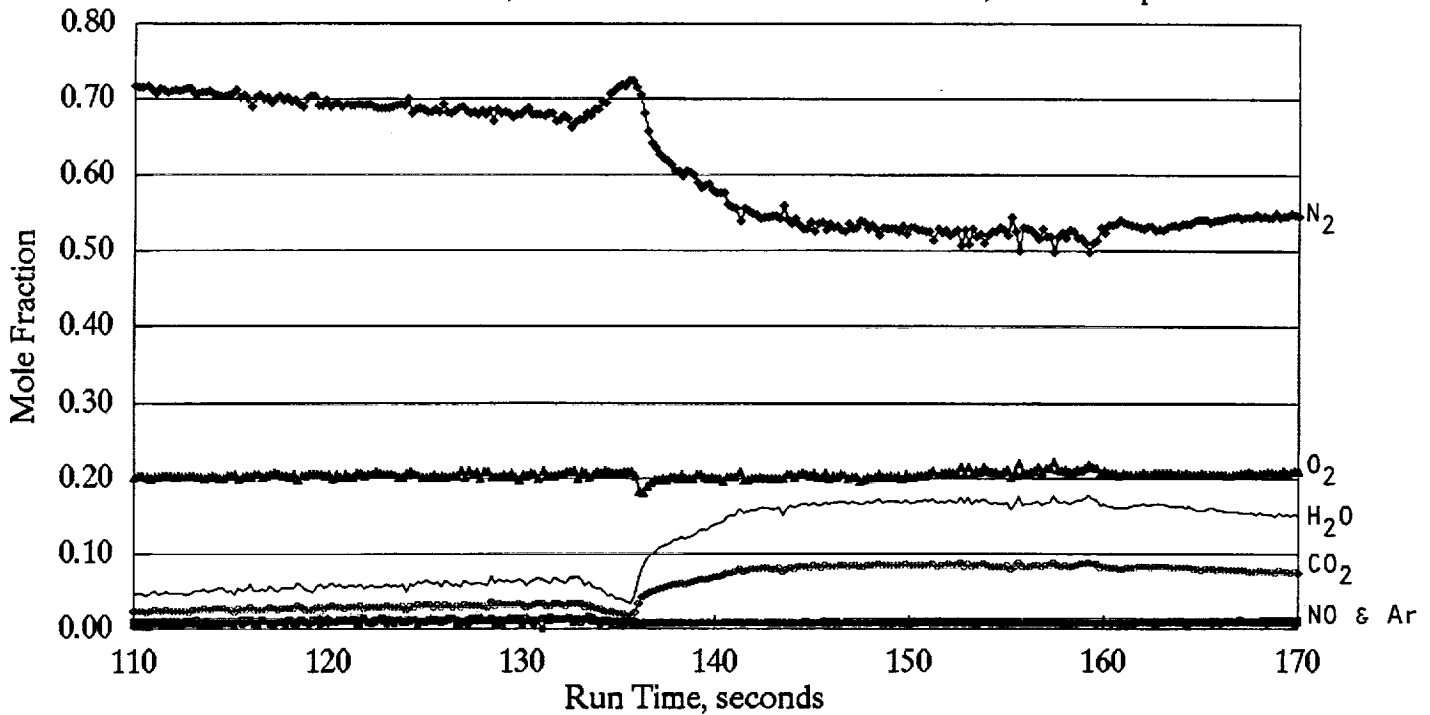
8' HTT Gas Analysis System

FSA Position, Test 139 Run 16



8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
— Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

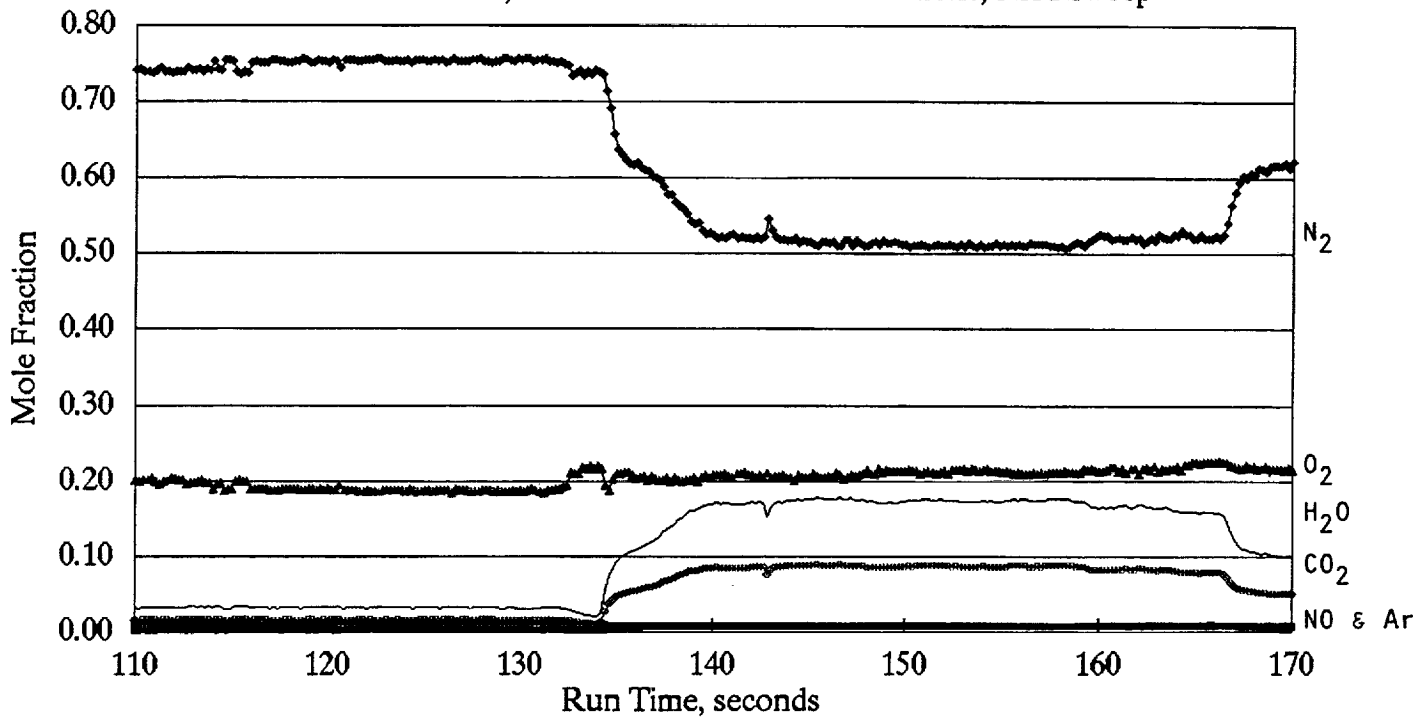
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen:	0.527	+/-	0.021
Oxygen:	0.204	+/-	0.016
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.084	+/-	0.007
H ₂ O:	0.168	+/-	0.014
Nitric oxide:	0.009	+/-	0.002

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



Sum of mole fractions = 1.

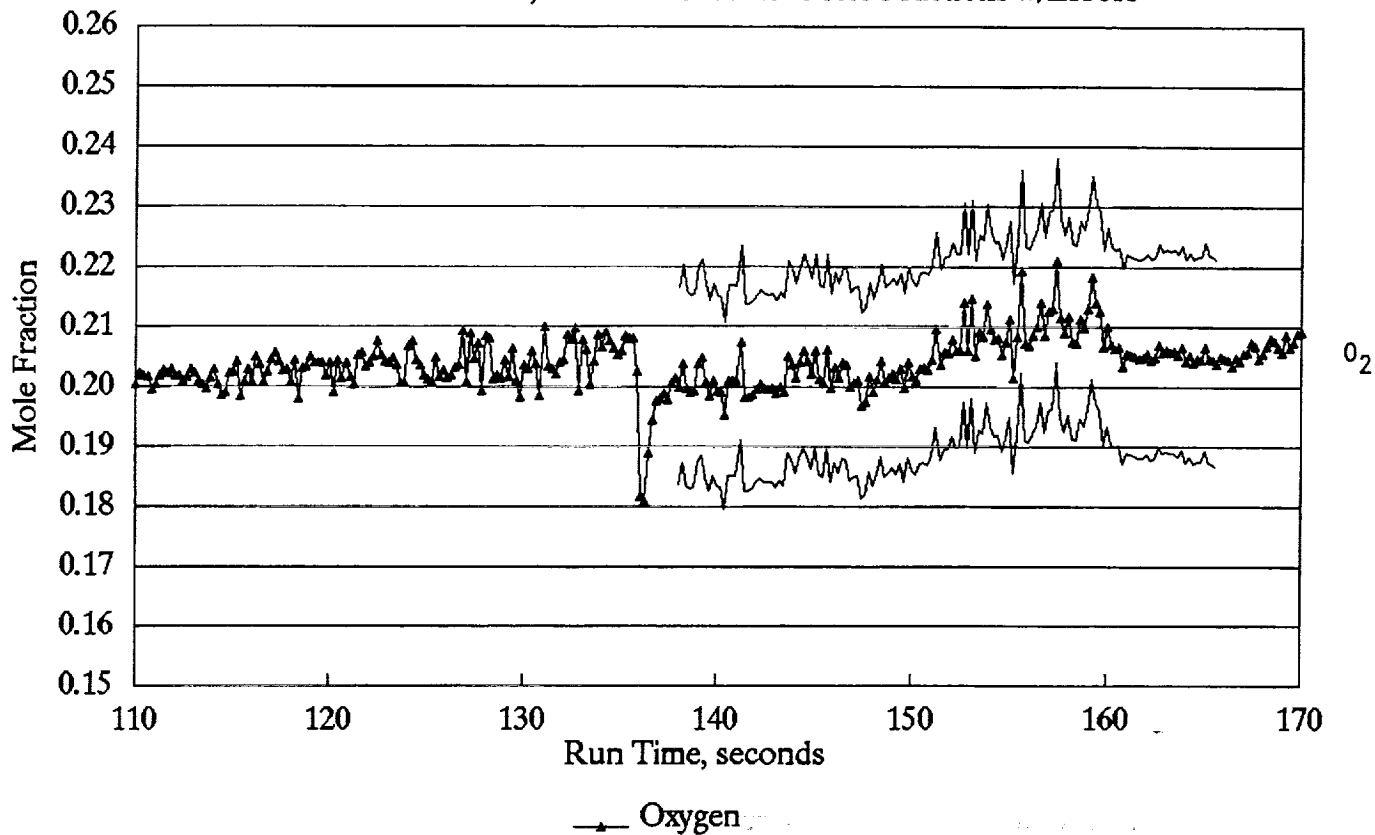
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen:	0.512	+/-	0.021
Oxygen:	0.211	+/-	0.015
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.087	+/-	0.008
H2O:	0.174	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

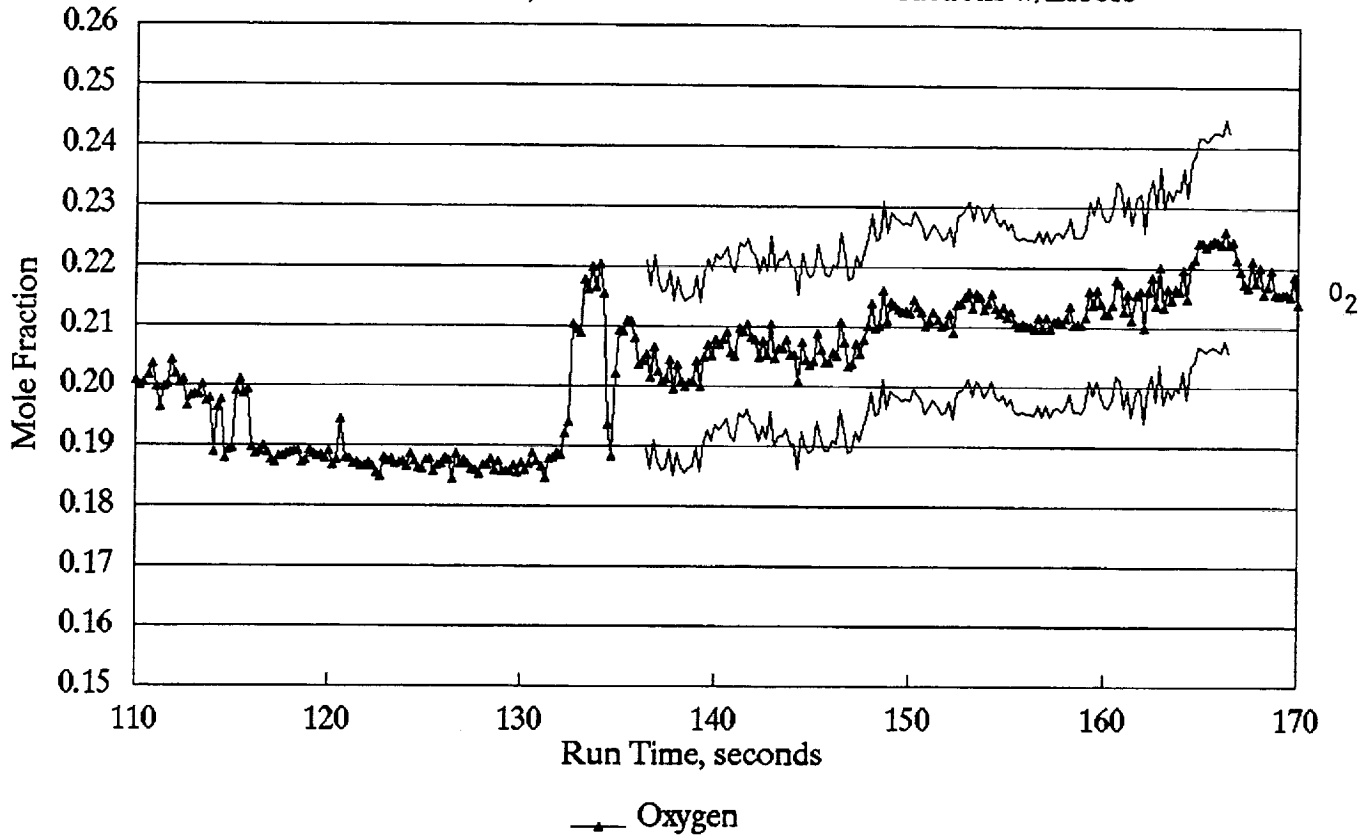
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Oxygen: 0.204 +/- 0.016

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

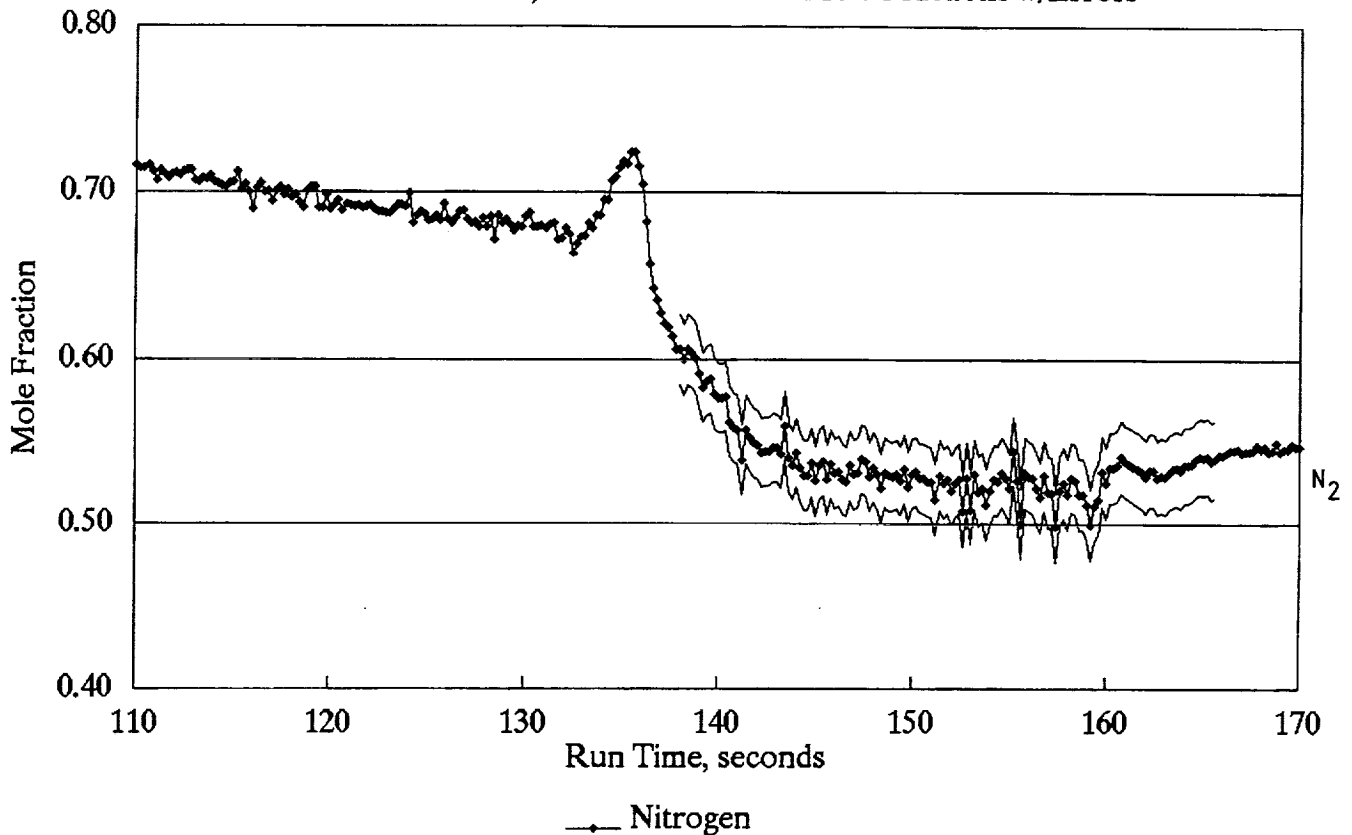
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Oxygen: 0.211 +/- 0.015

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

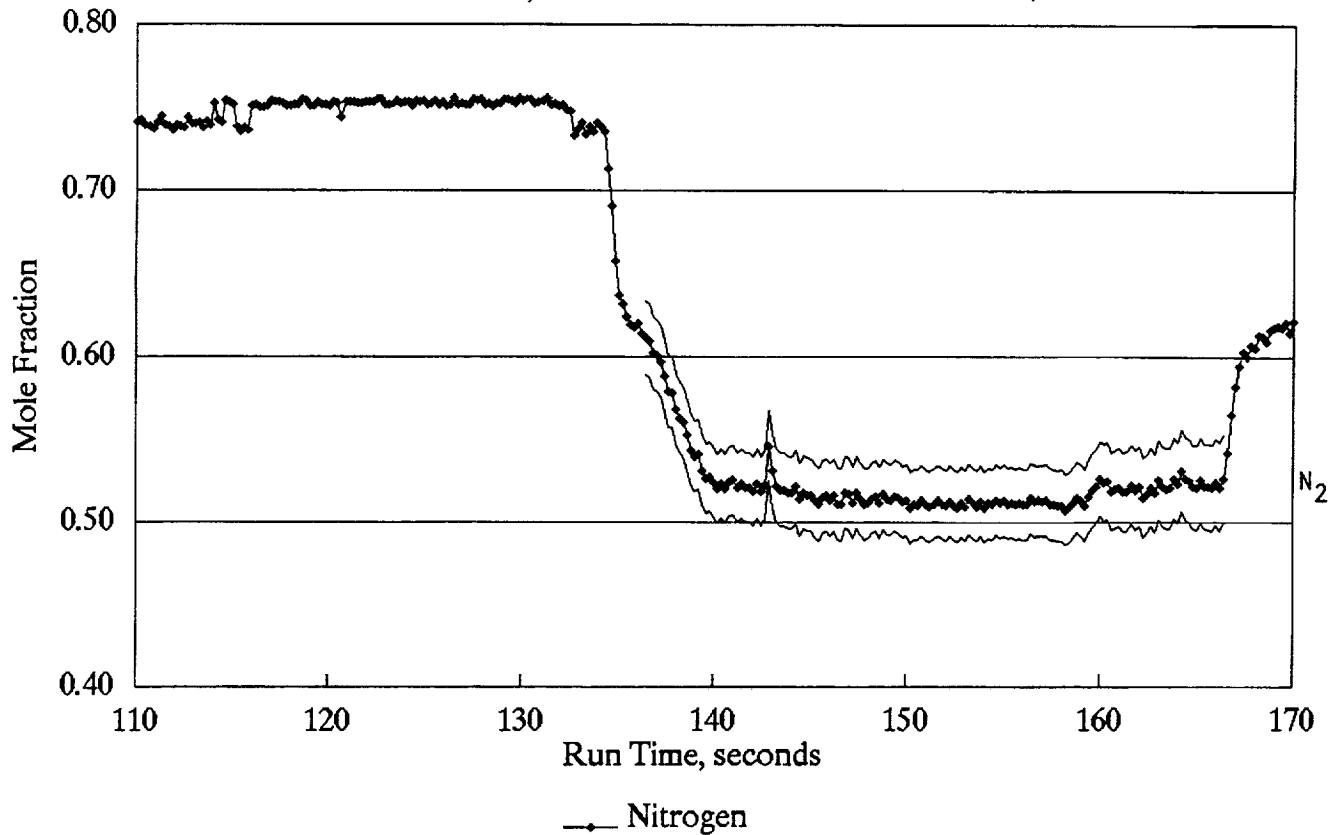
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen: 0.527 +/- 0.021

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

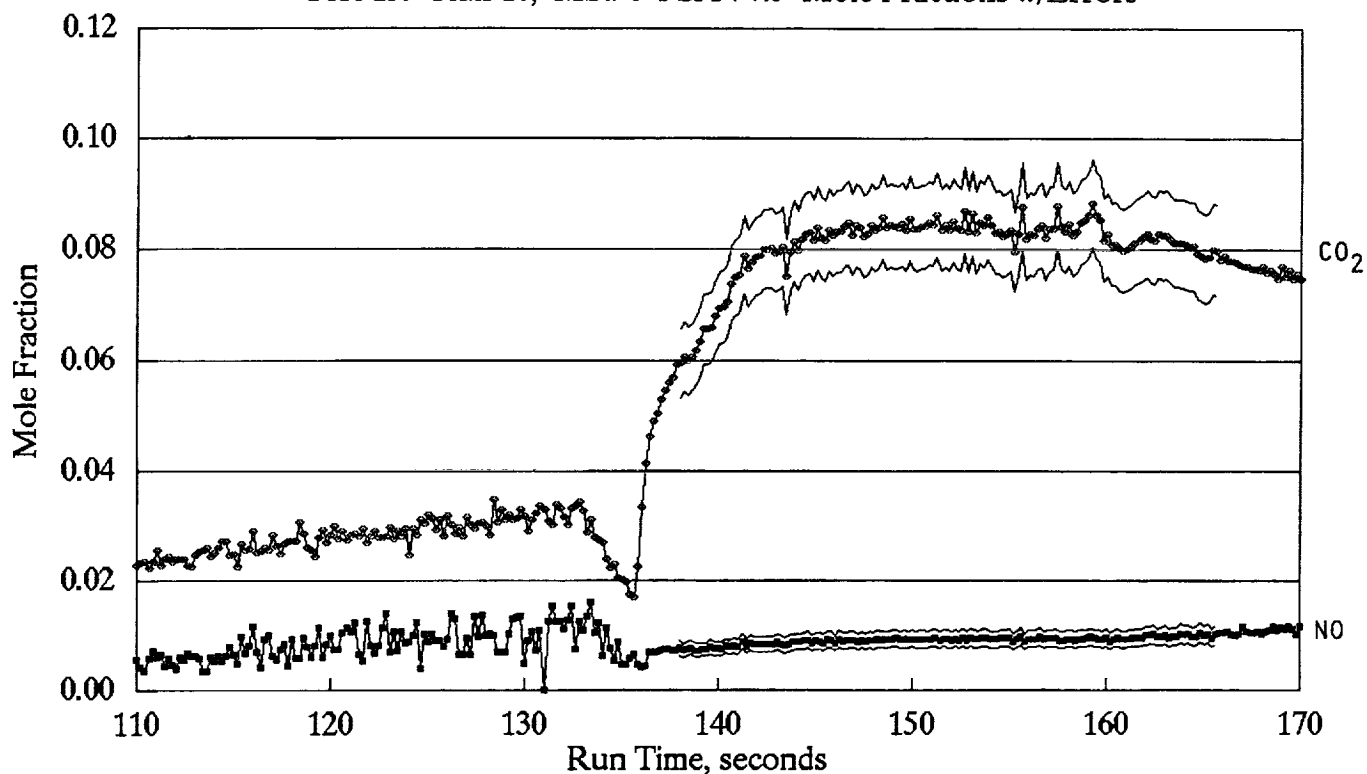
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen: 0.512 +/- 0.021

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

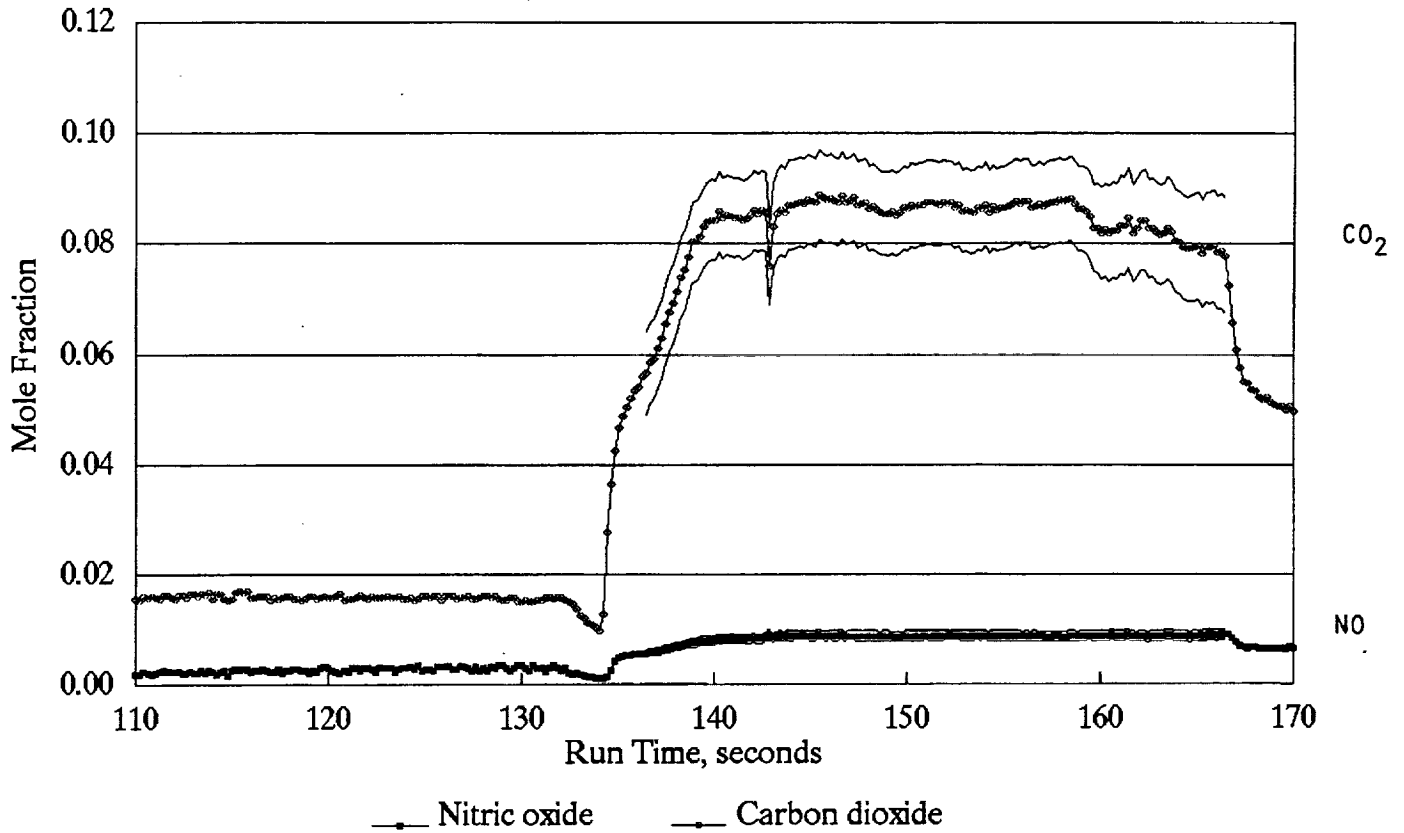
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Carbon dioxide:	0.084	+/-	0.007
Nitric oxide:	0.009	+/-	0.002

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

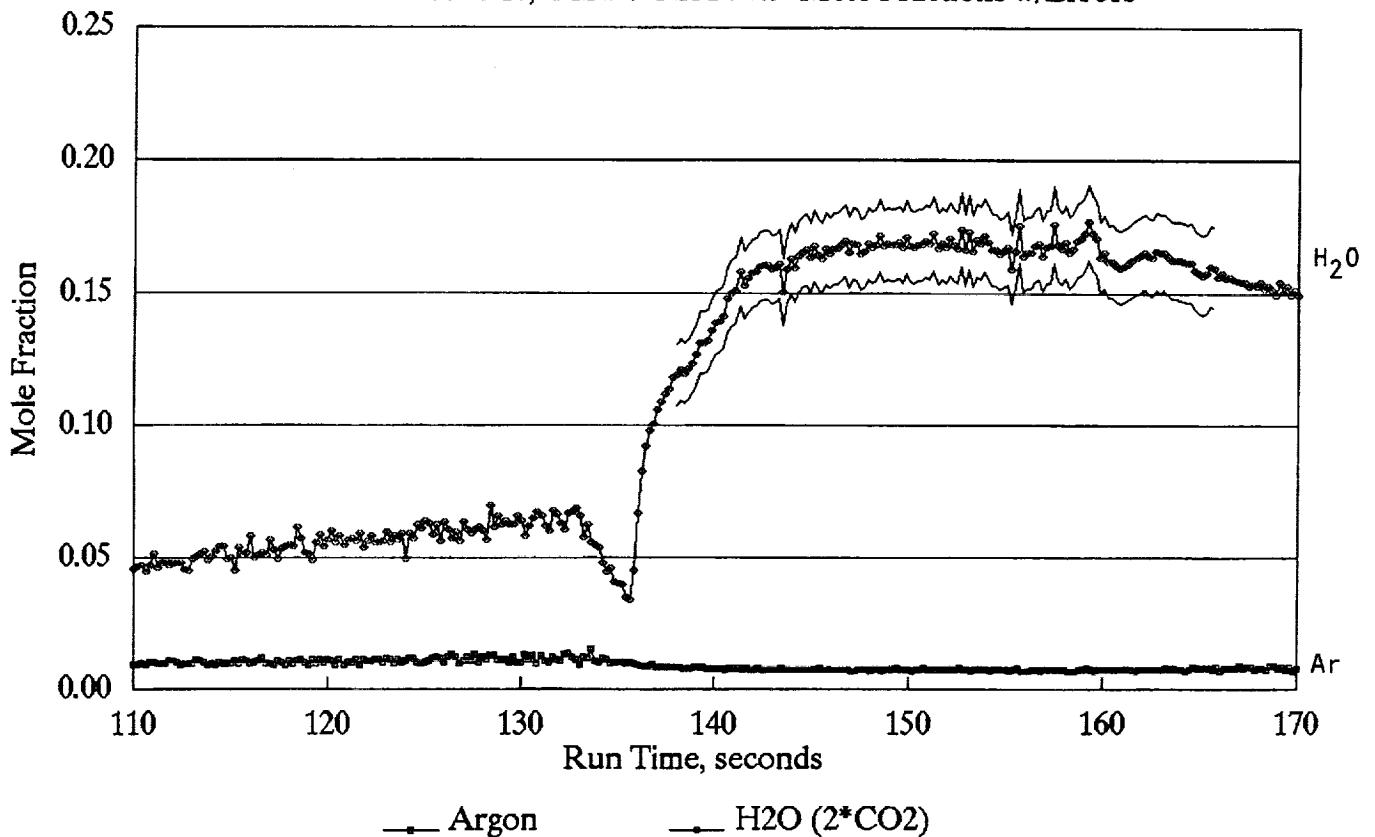
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Carbon dioxide:	0.087	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

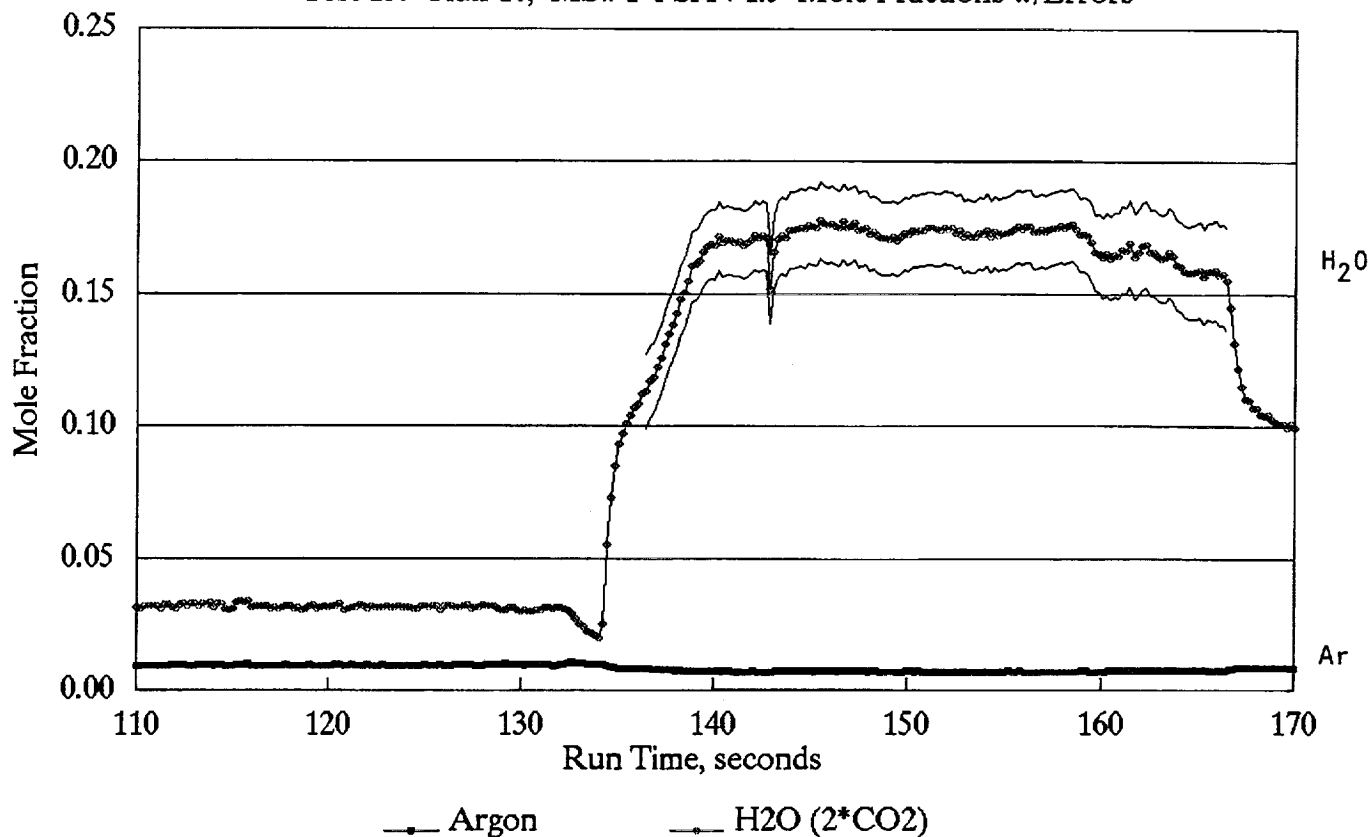
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.168	+/-	0.014

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA + 1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

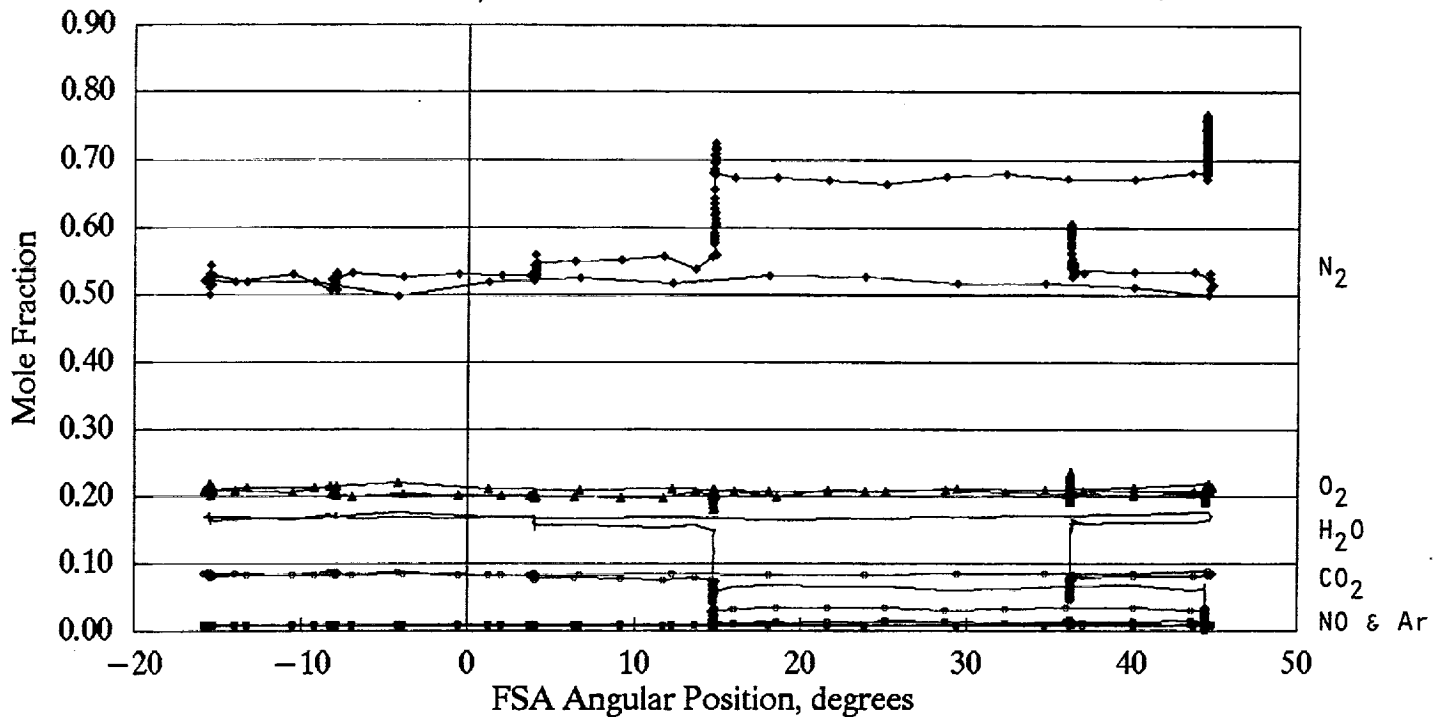
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.174	+/-	0.014

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

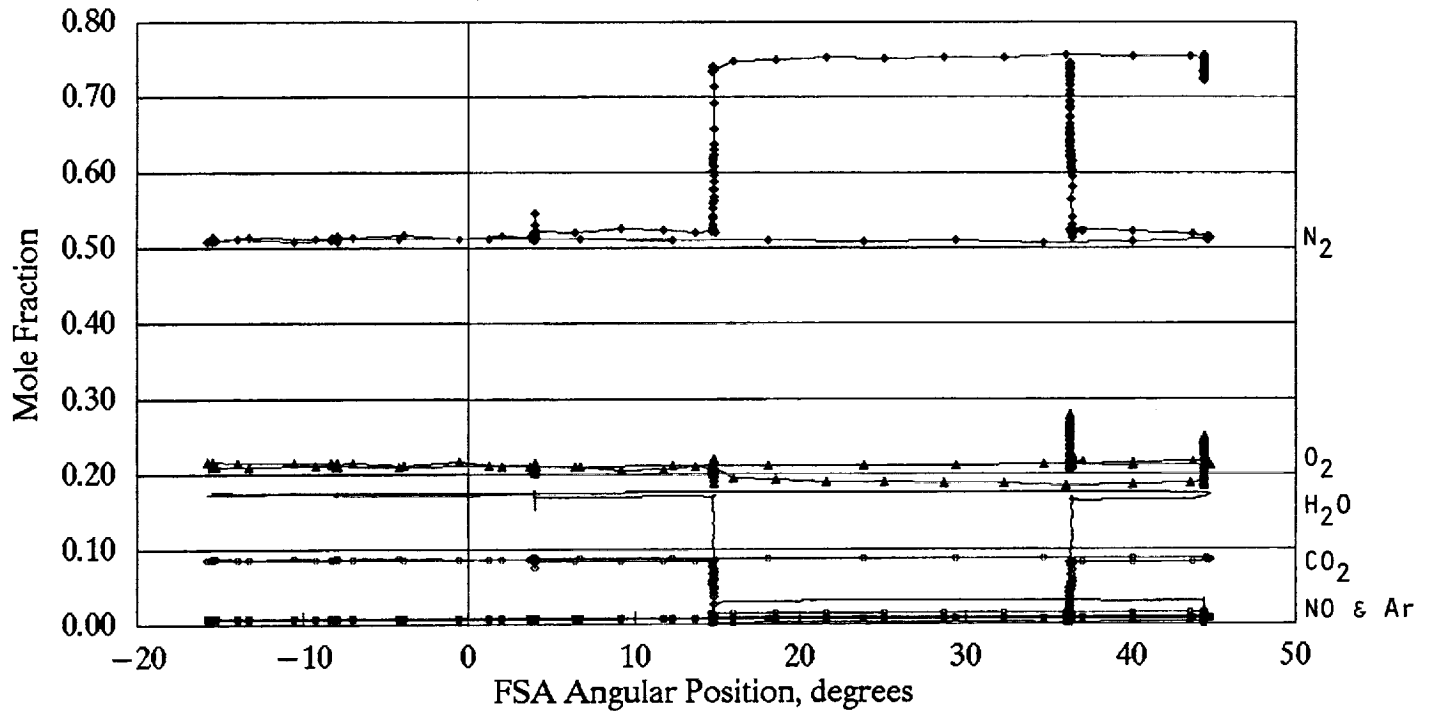
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen:	0.527	+/-	0.021
Oxygen:	0.204	+/-	0.016
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.084	+/-	0.007
H ₂ O:	0.168	+/-	0.014
Nitric oxide:	0.009	+/-	0.002

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

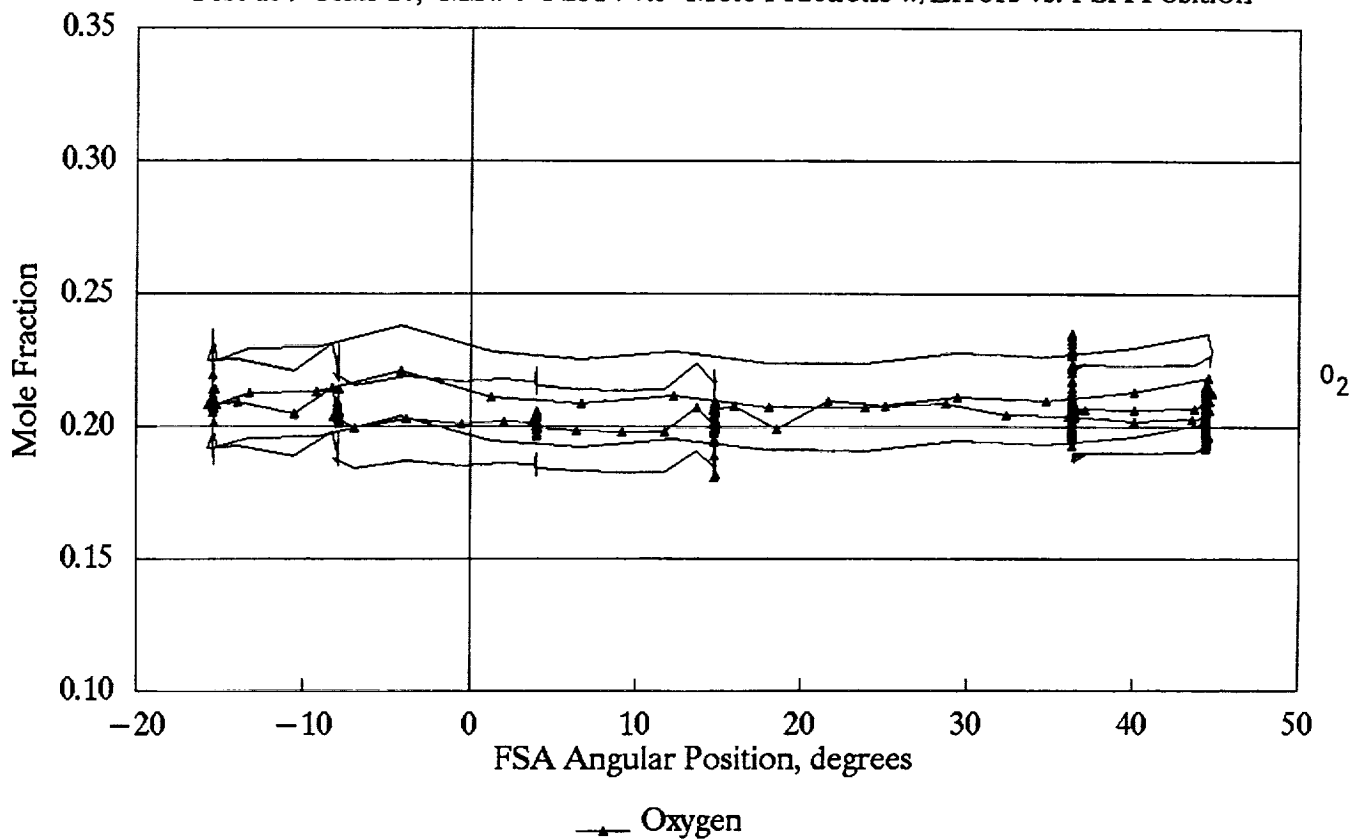
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Nitrogen:	0.512	+/-	0.021
Oxygen:	0.211	+/-	0.015
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.087	+/-	0.008
H ₂ O:	0.174	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

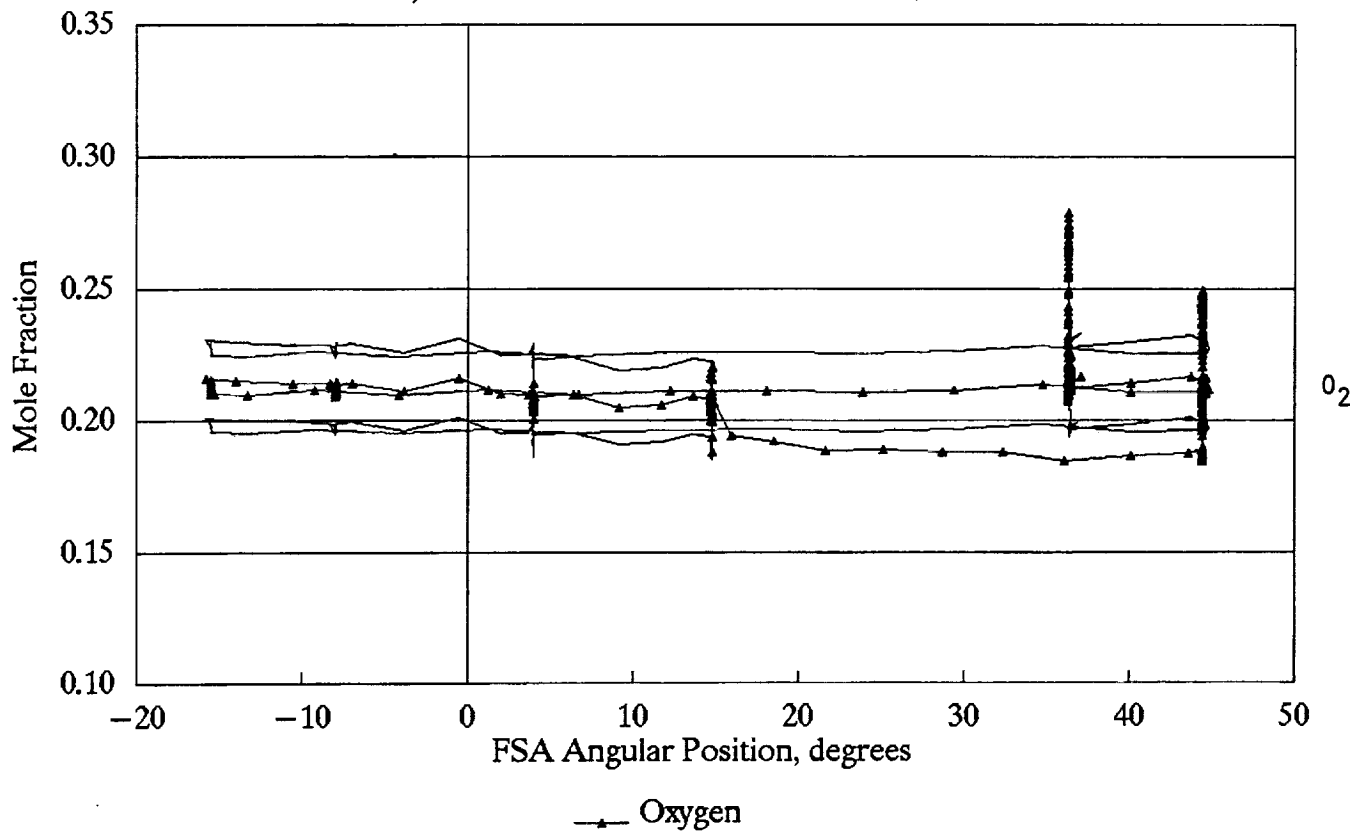
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Oxygen: 0.204 +/- 0.016

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

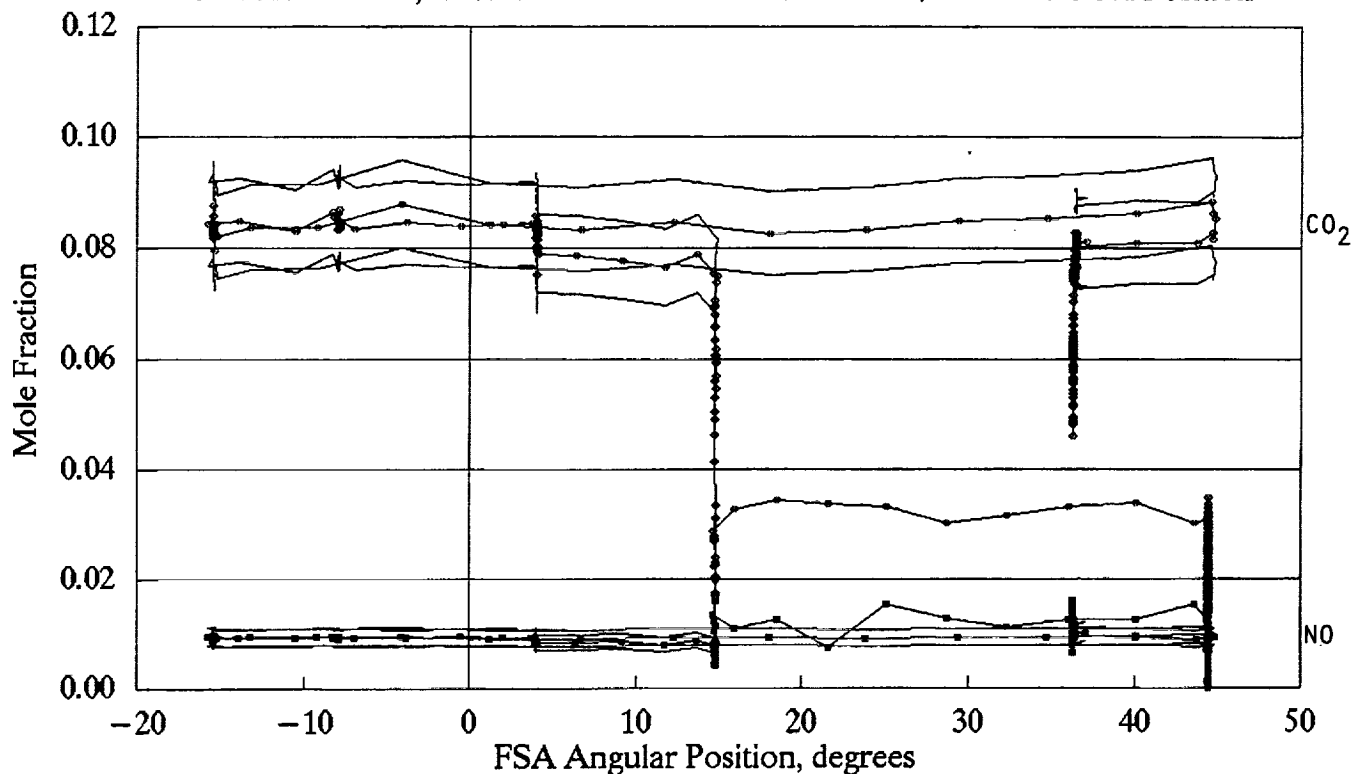
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Oxygen: 0.211 +/- 0.015

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

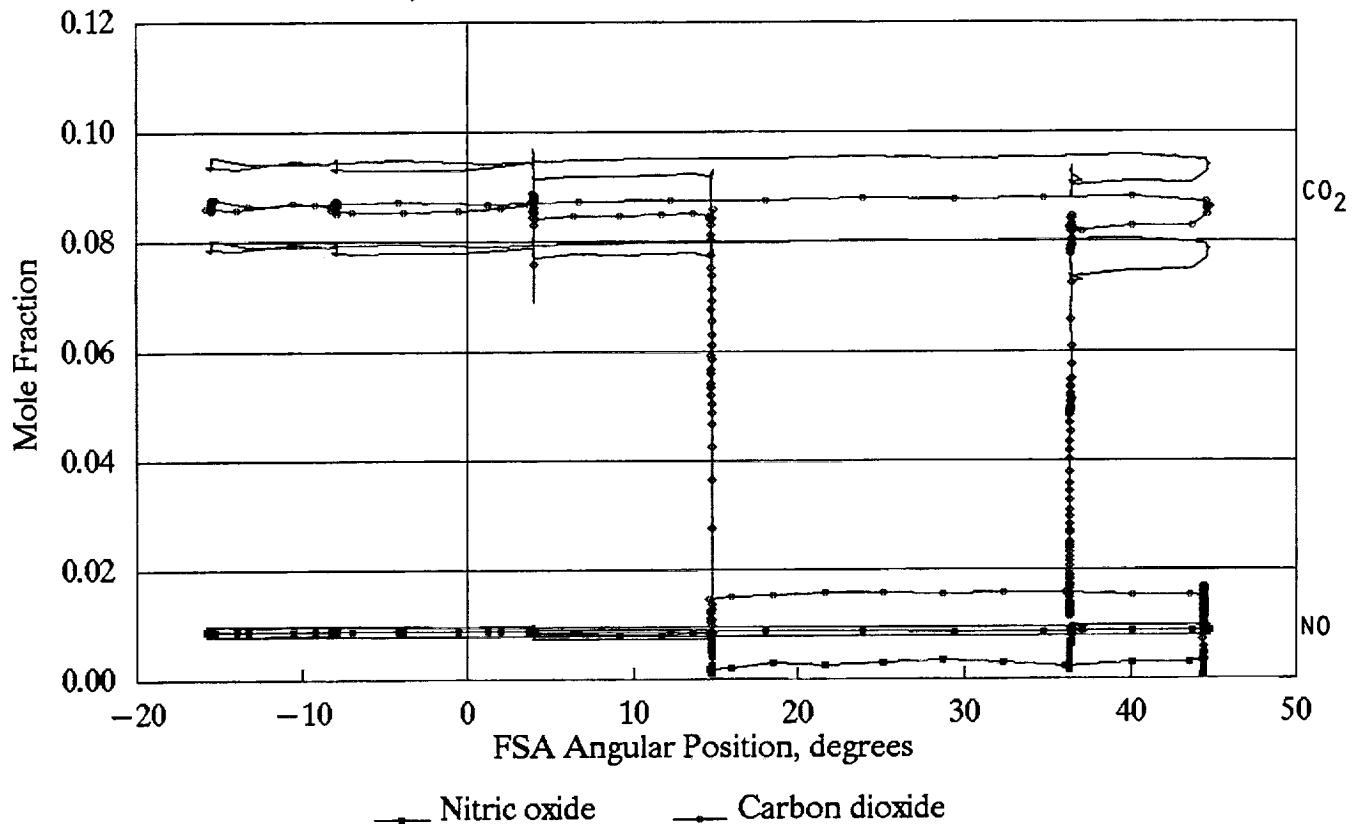
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Carbon dioxide:	0.084	+/-	0.007
Nitric oxide:	0.009	+/-	0.002

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

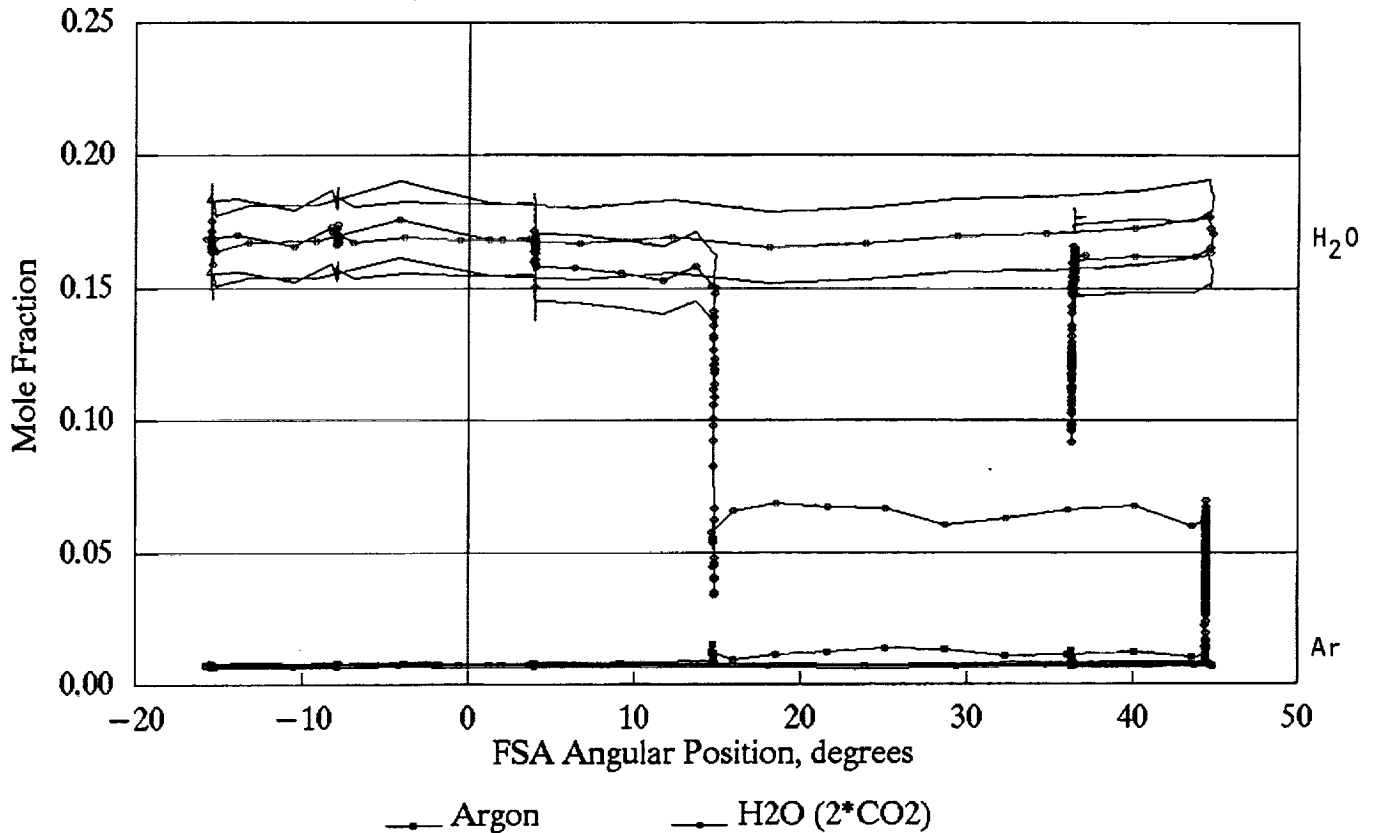
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Carbon dioxide:	0.087	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 16, MS#0 FSA+7.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

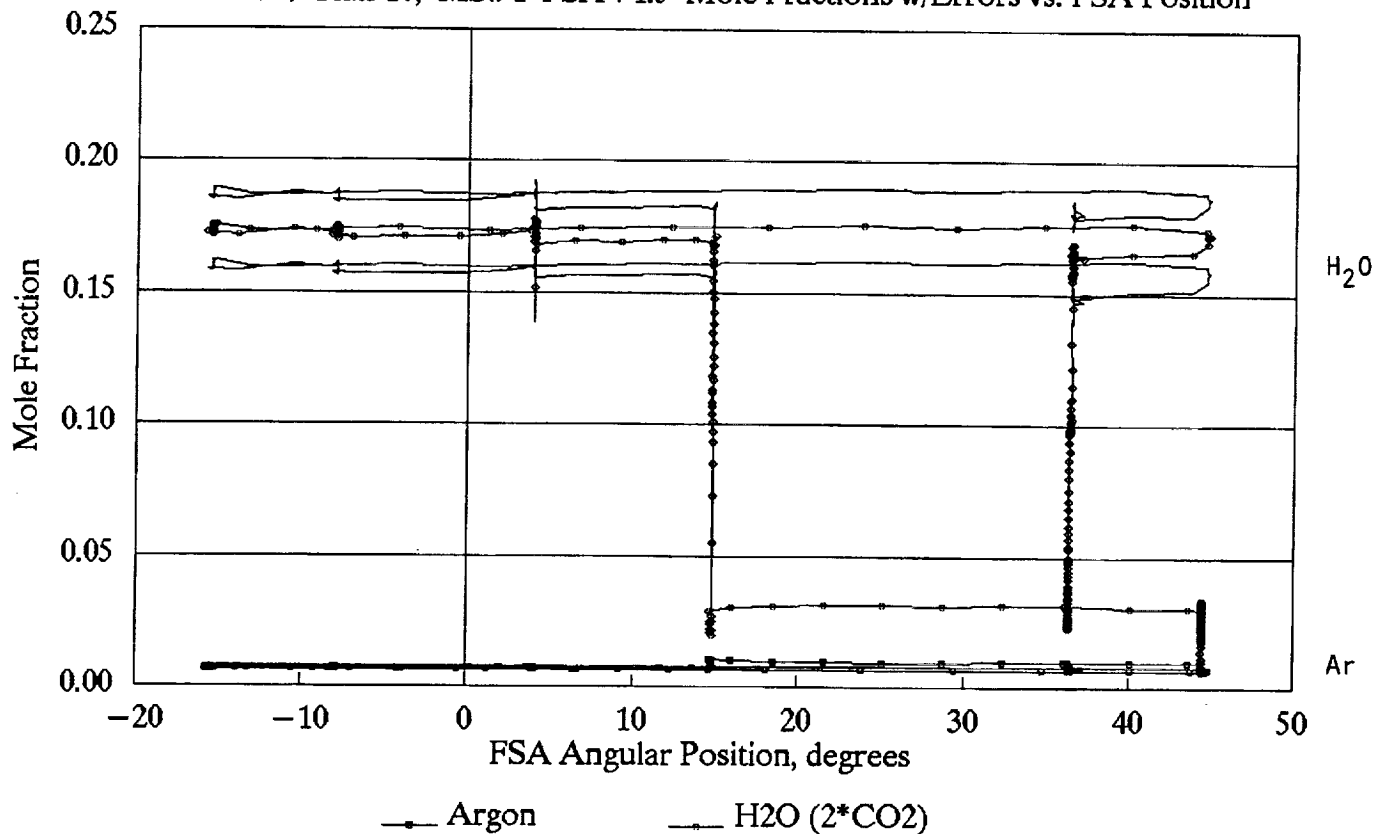
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.168	+/-	0.014

8' HTT Gas Analysis System

Test 139 Run 16, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 145 to 155 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.174	+/-	0.014

Test 139 Run 17

Combustor Pressure: 1000 psia

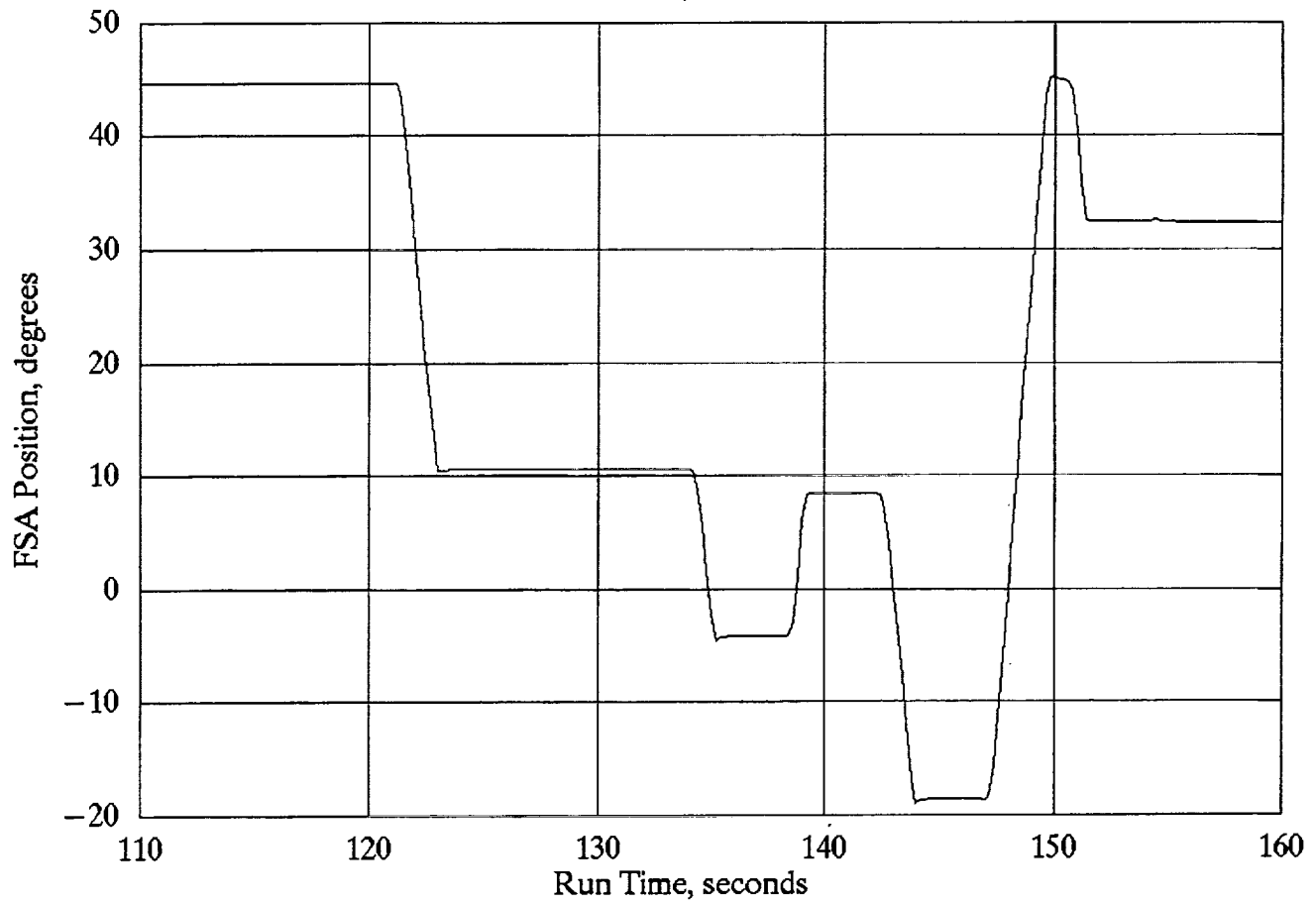
Combustor Temperature: 3400 R

Normal Stop: 152.0 seconds

Probes: FSA+1.5, FSA-1.5

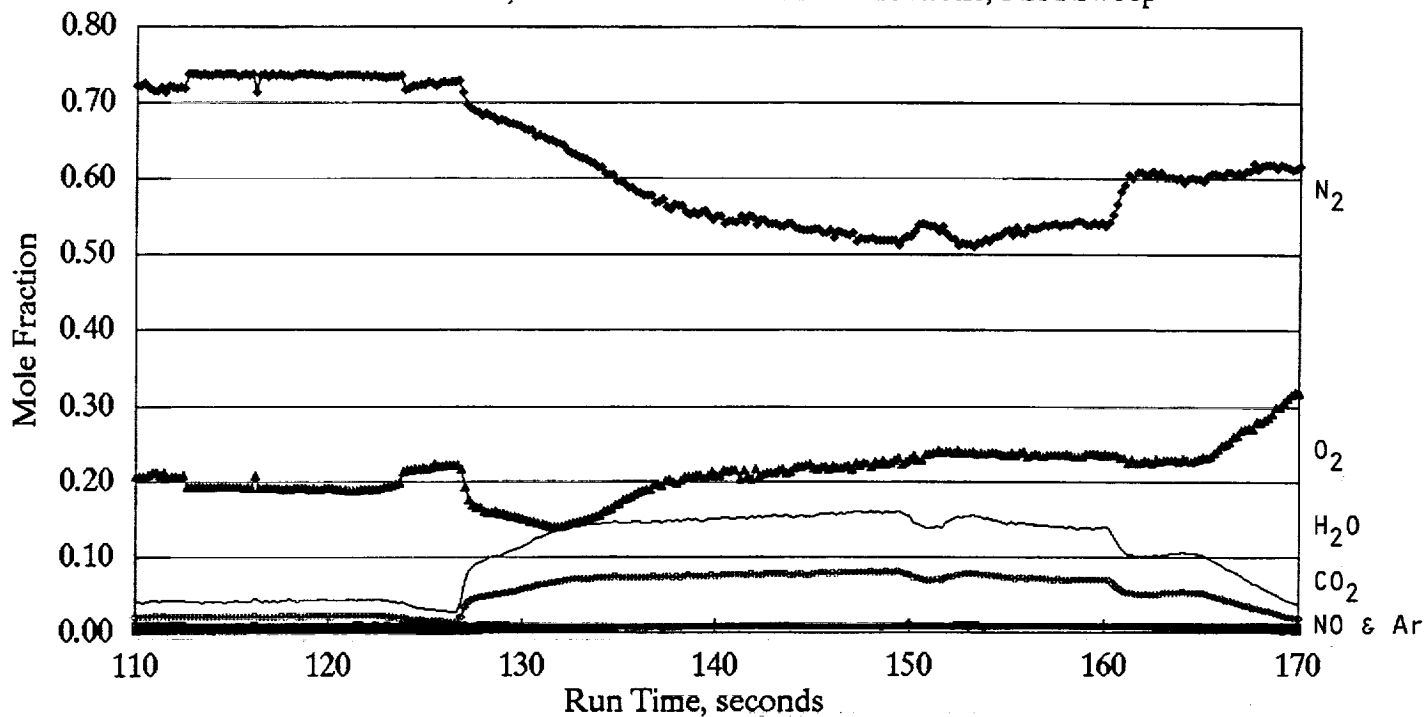
8' HTT Gas Analysis System

FSA Position, Test 139 Run 17



8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
— Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

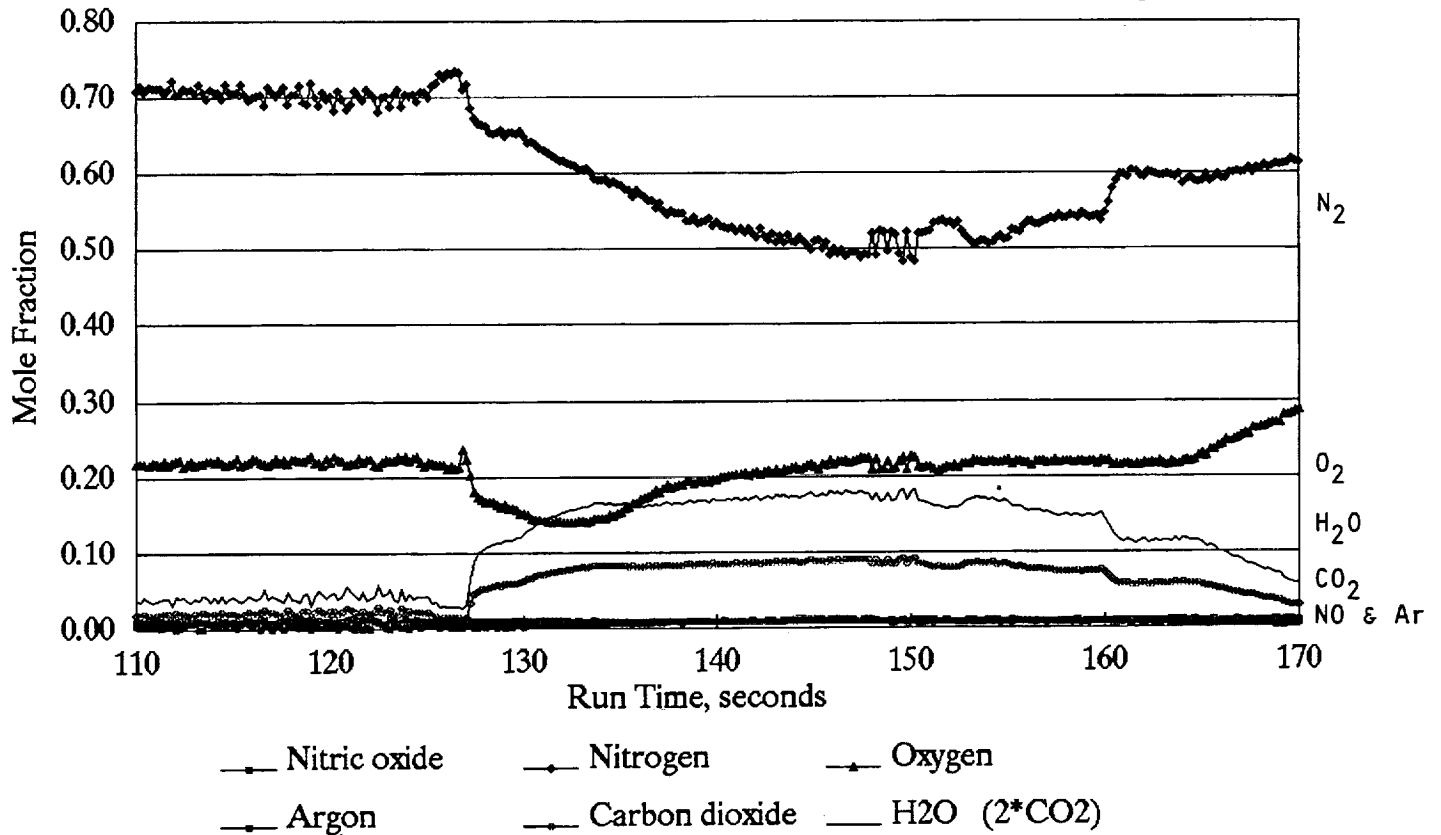
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.533	+/-	0.024
Oxygen:	0.218	+/-	0.016
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.078	+/-	0.010
H ₂ O:	0.155	+/-	0.019
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions, FSA Sweep



Sum of mole fractions = 1.

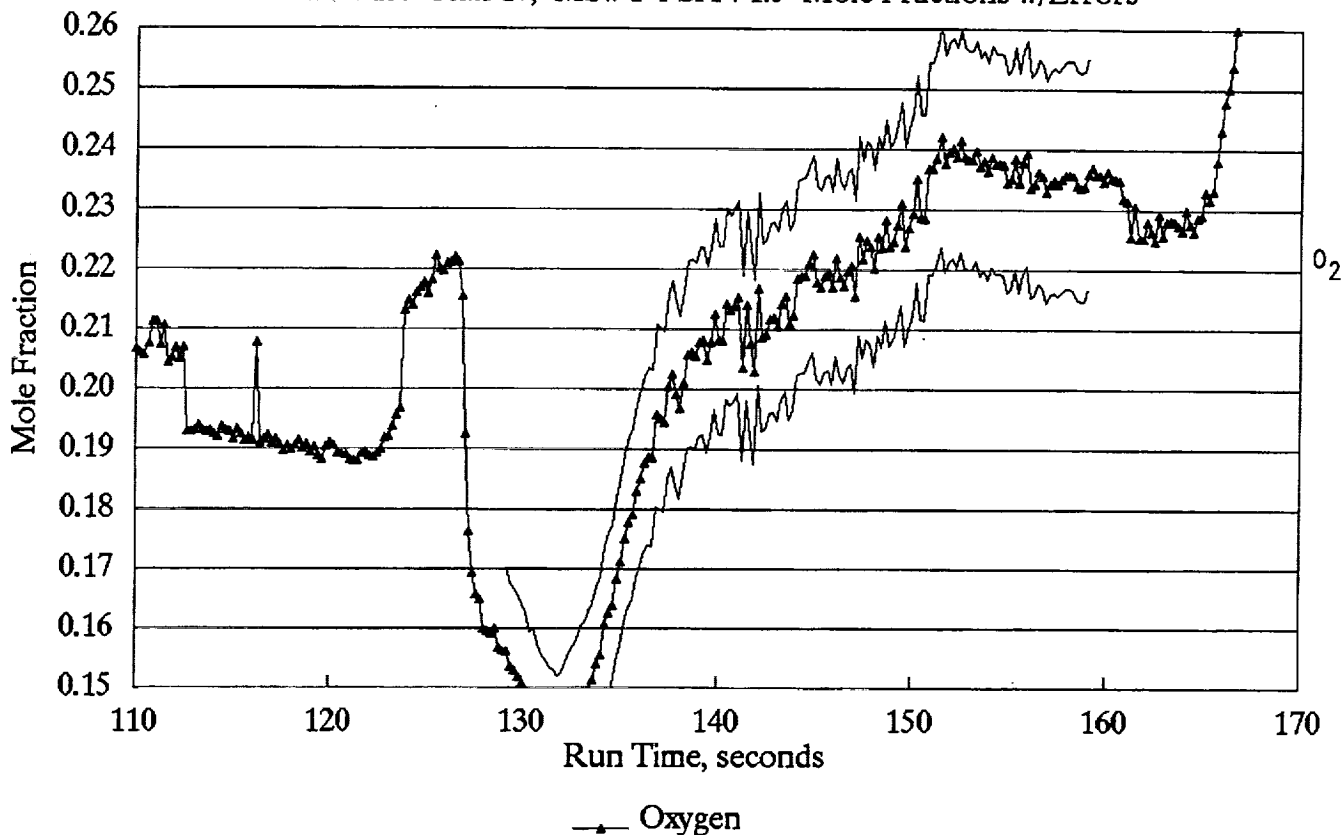
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.510	+/-	0.024
Oxygen:	0.212	+/-	0.018
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.087	+/-	0.008
H2O:	0.174	+/-	0.015
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

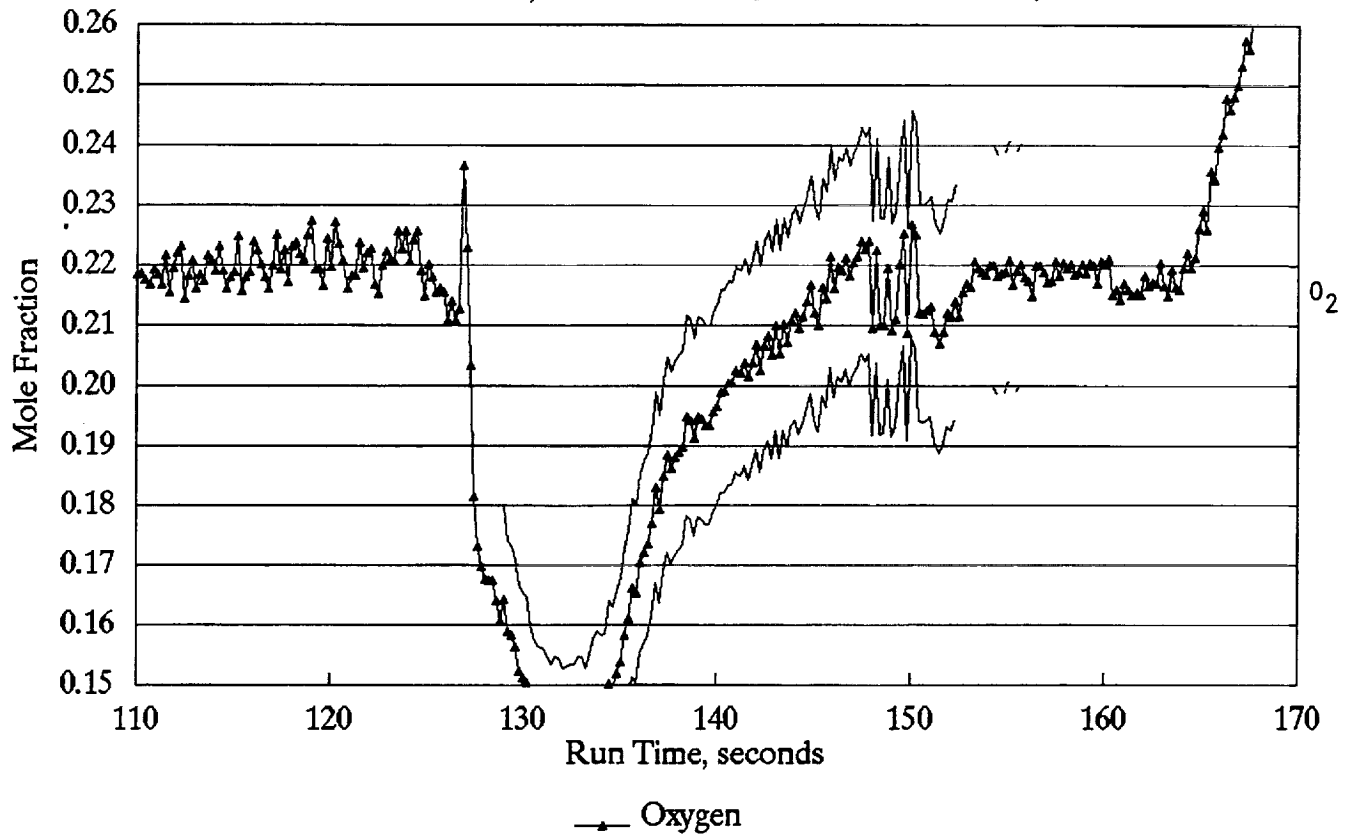
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.218 +/- 0.016

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

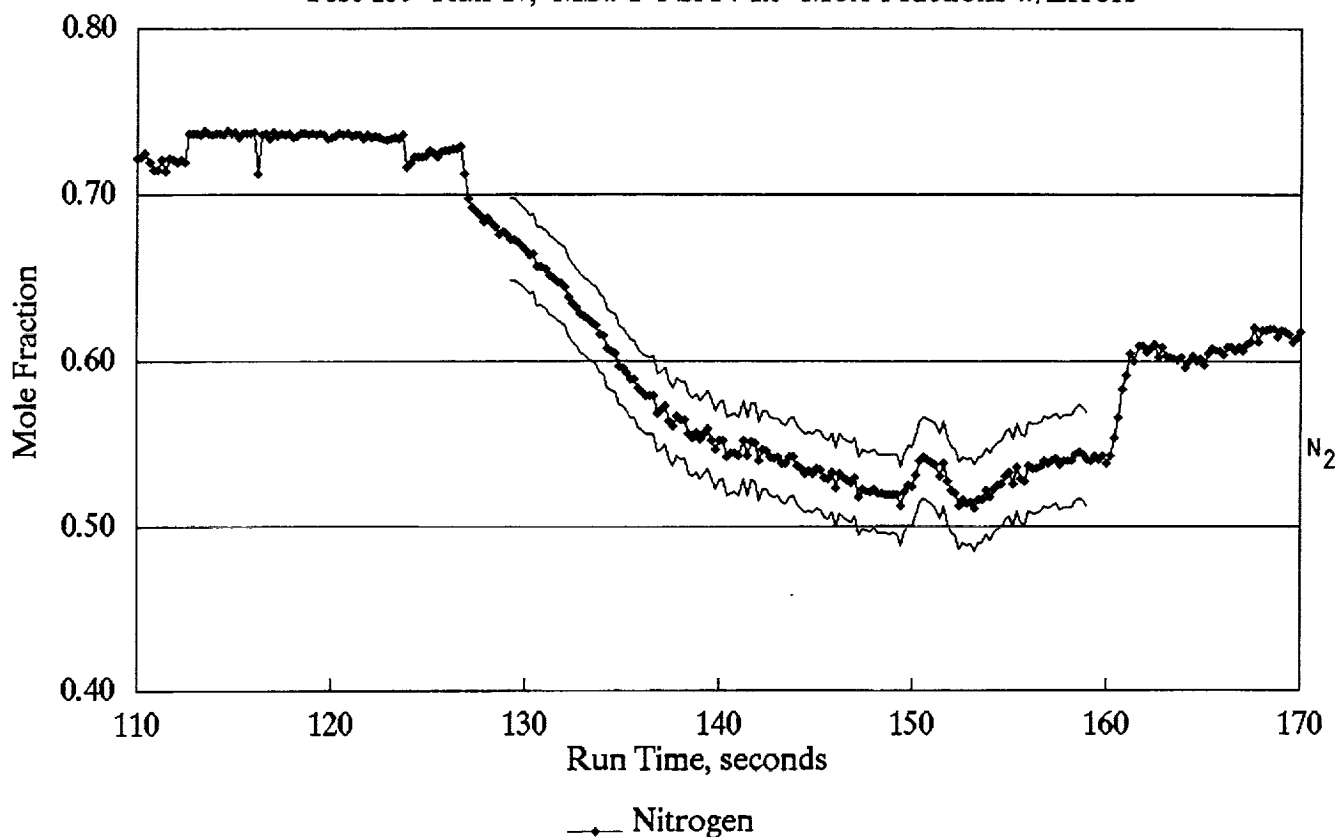
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.212 +/- 0.018

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

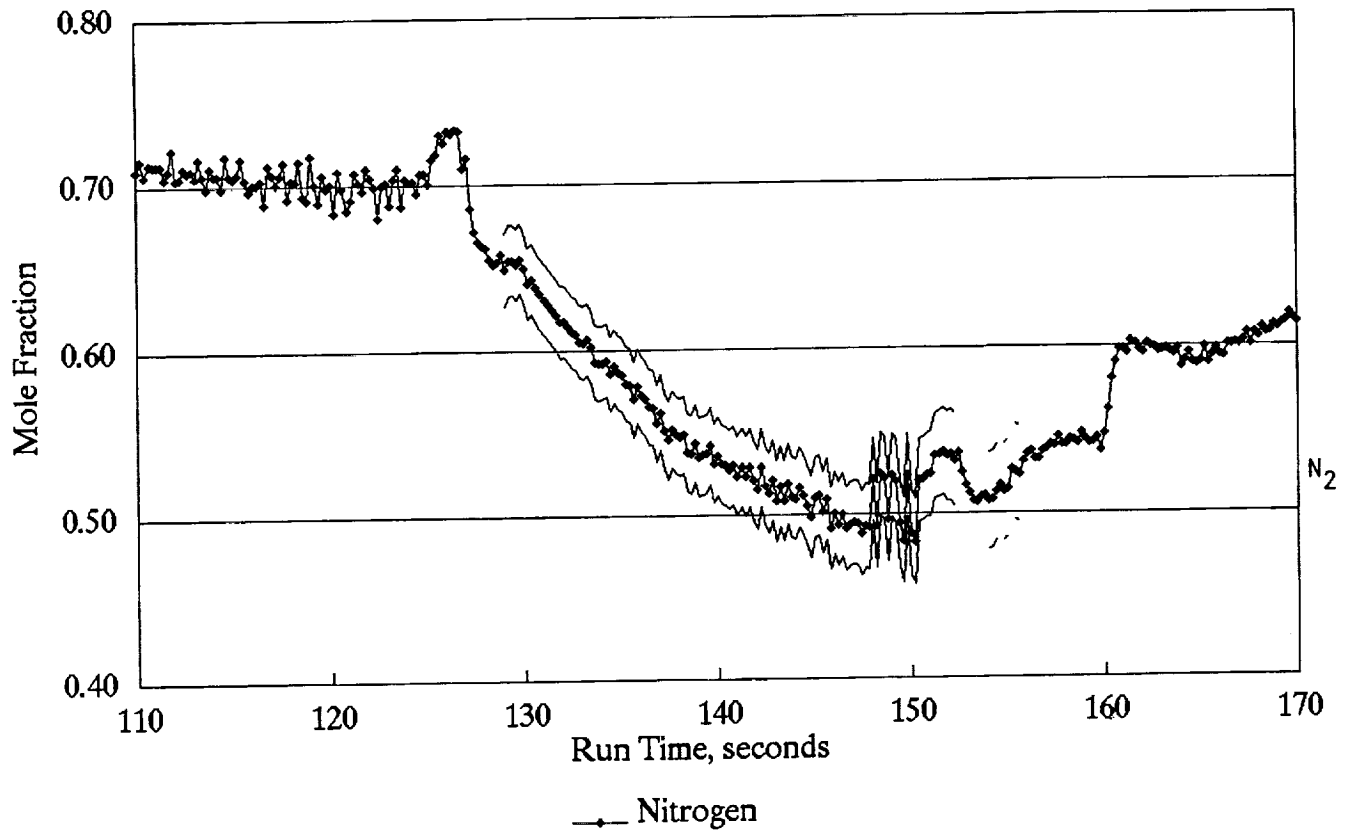
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.533 +/- 0.024

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

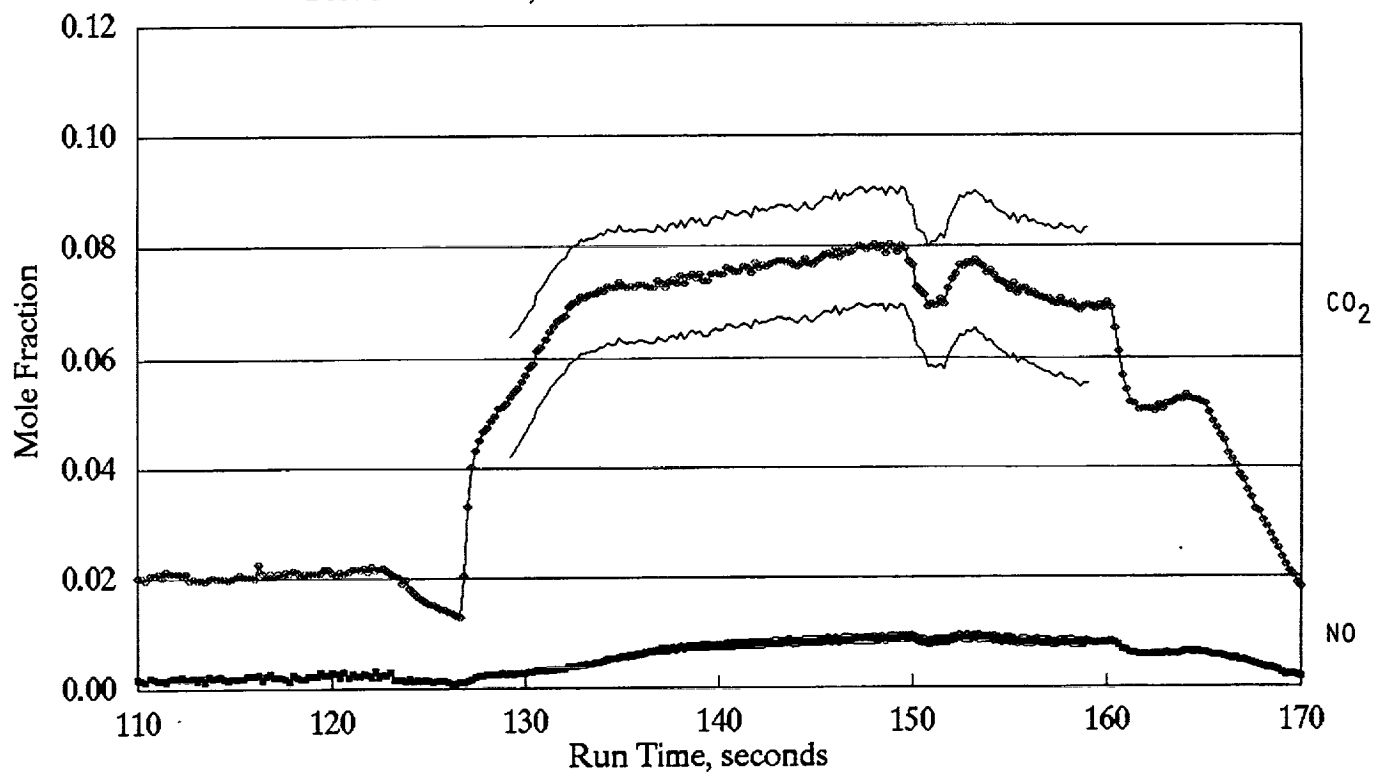
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen: 0.510 +/- 0.024

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

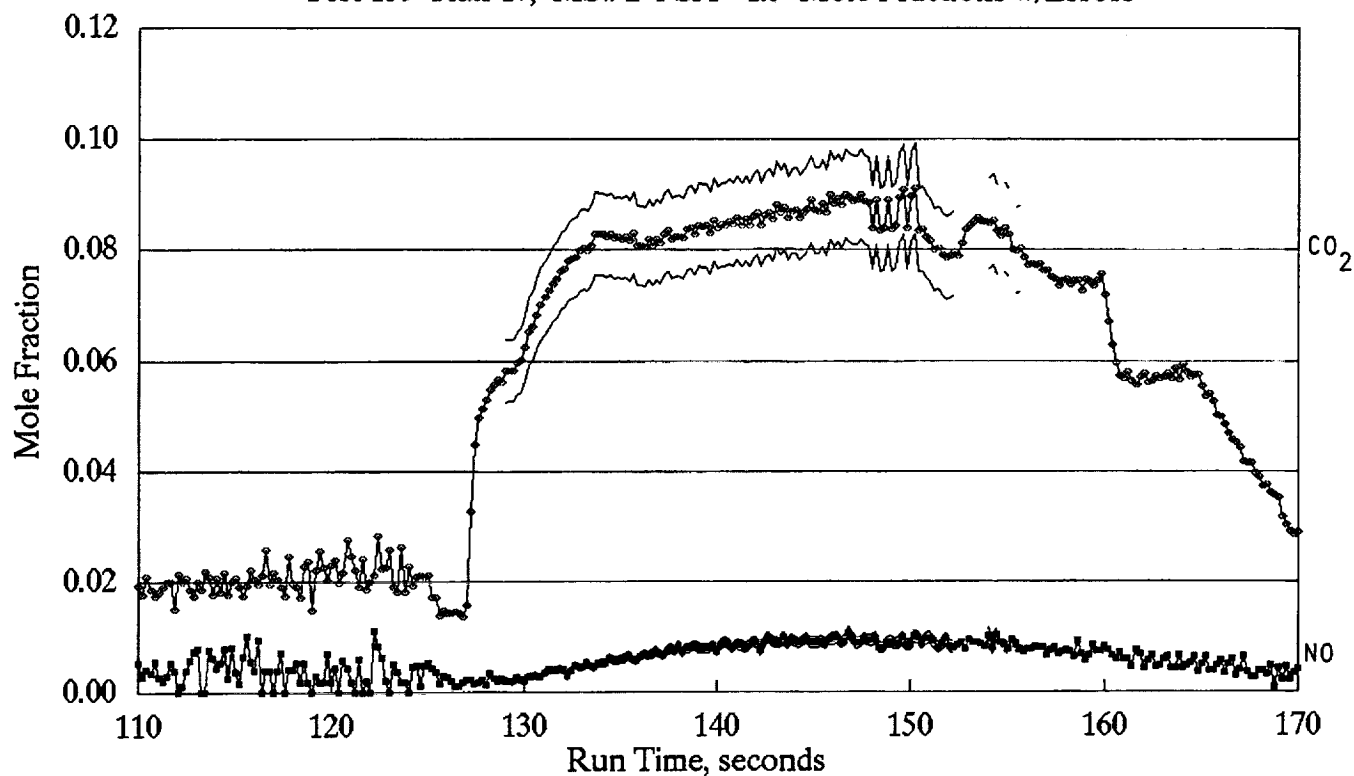
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.078	+/-	0.010
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

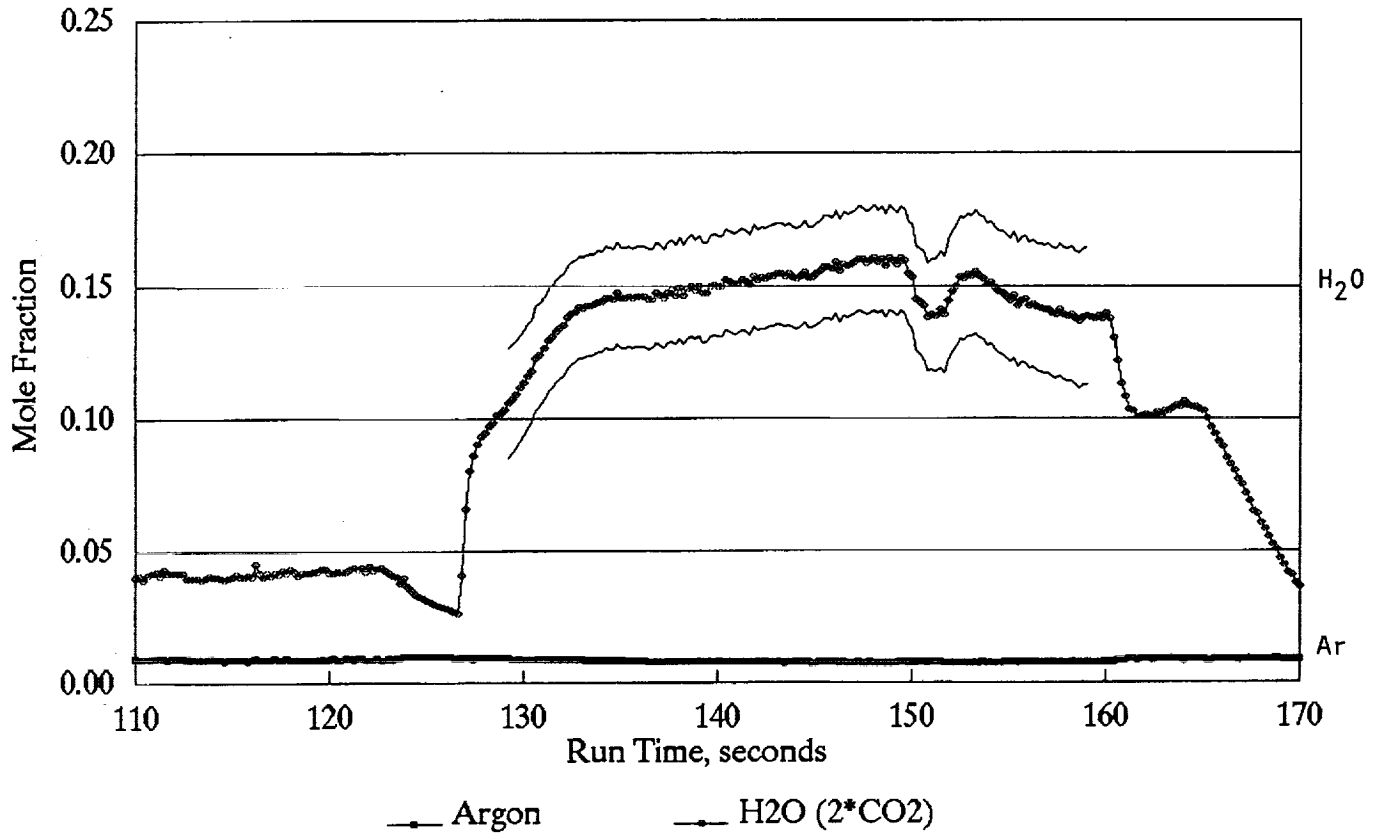
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.087	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

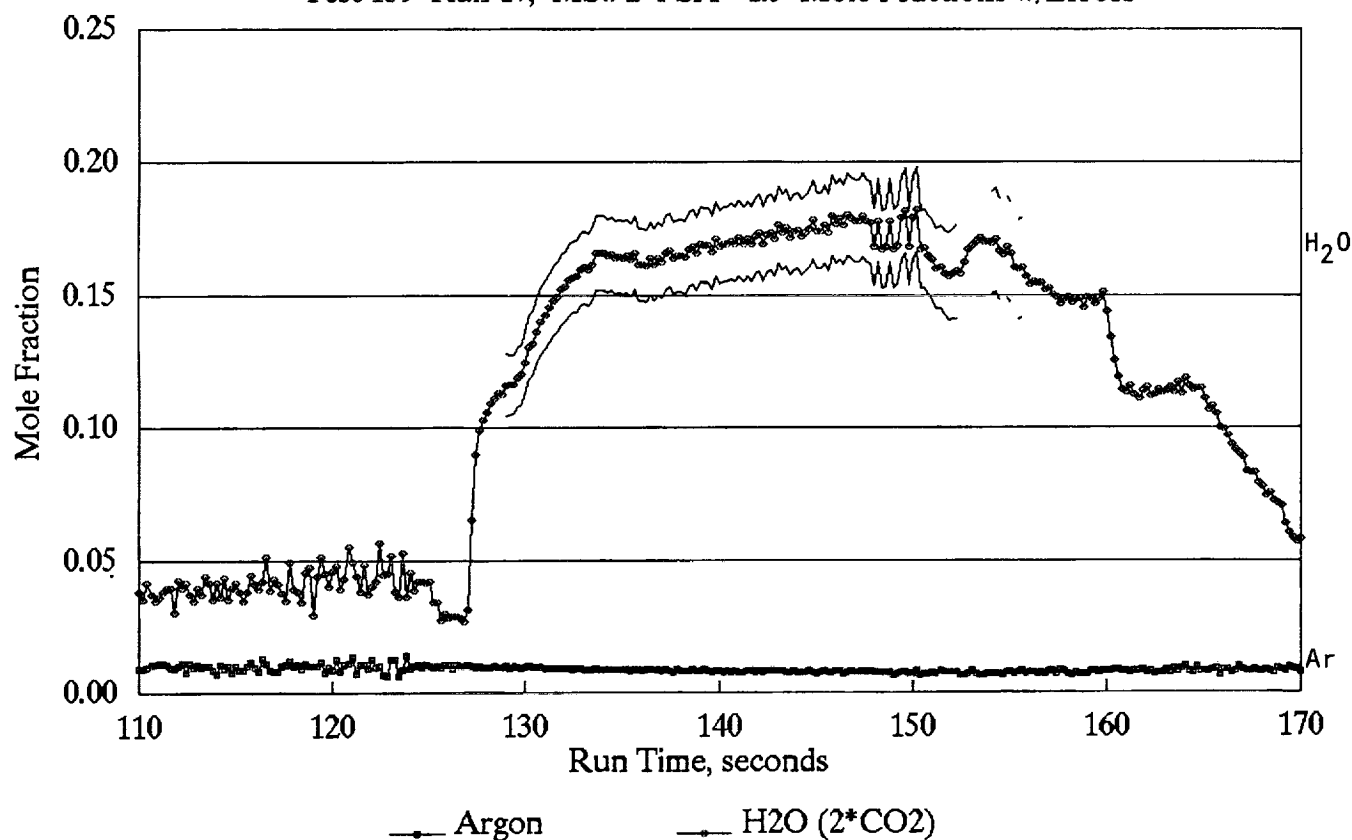
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.008	+/-	0.001
H ₂ O:	0.155	+/-	0.019

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

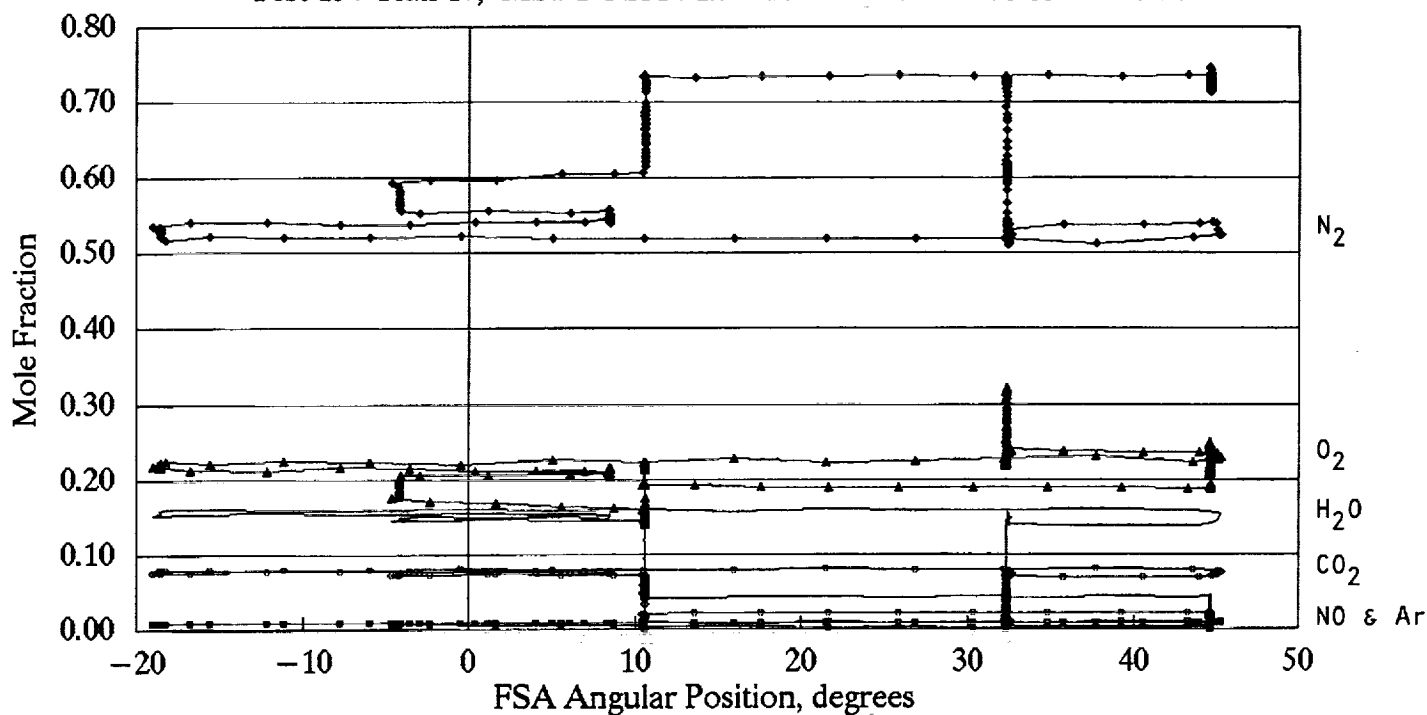
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.008	+/-	0.001
H ₂ O:	0.174	+/-	0.015

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

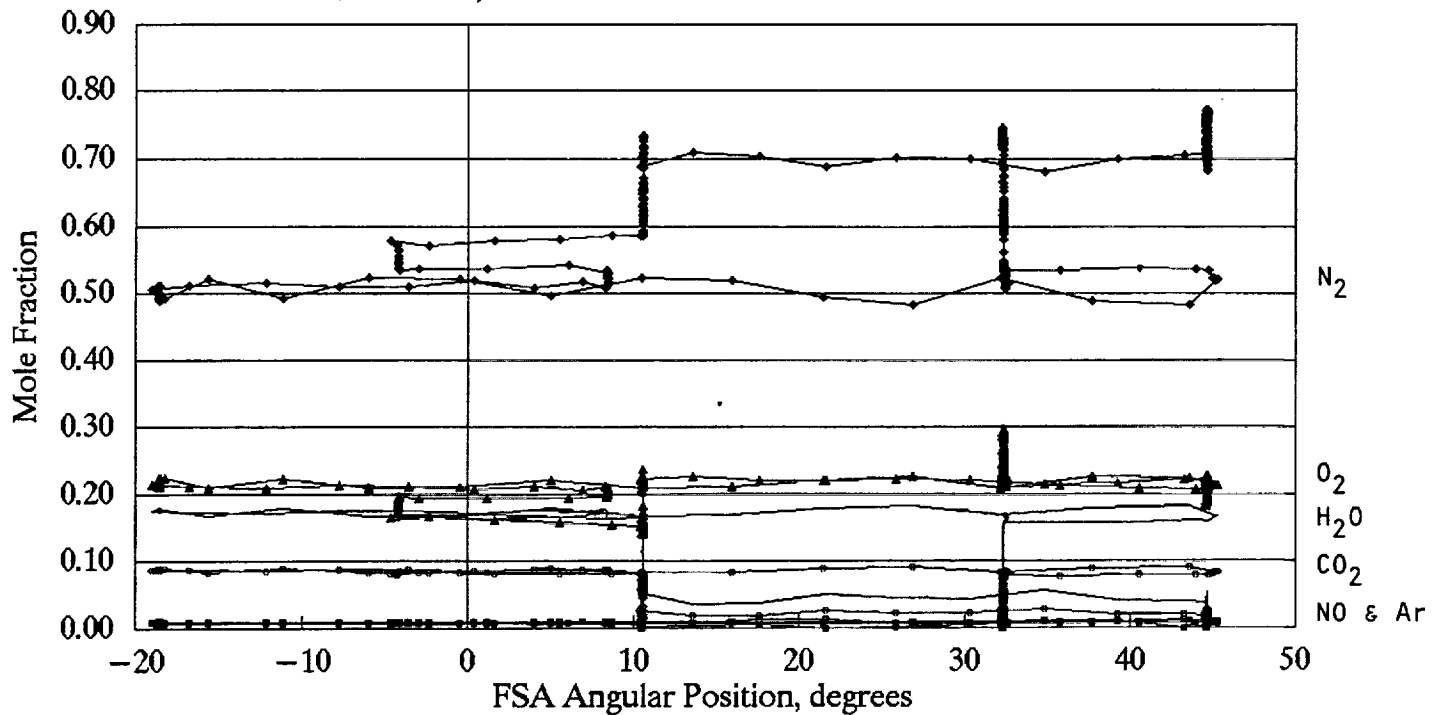
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.533	+/-	0.024
Oxygen:	0.218	+/-	0.016
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.078	+/-	0.010
H2O:	0.155	+/-	0.019
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

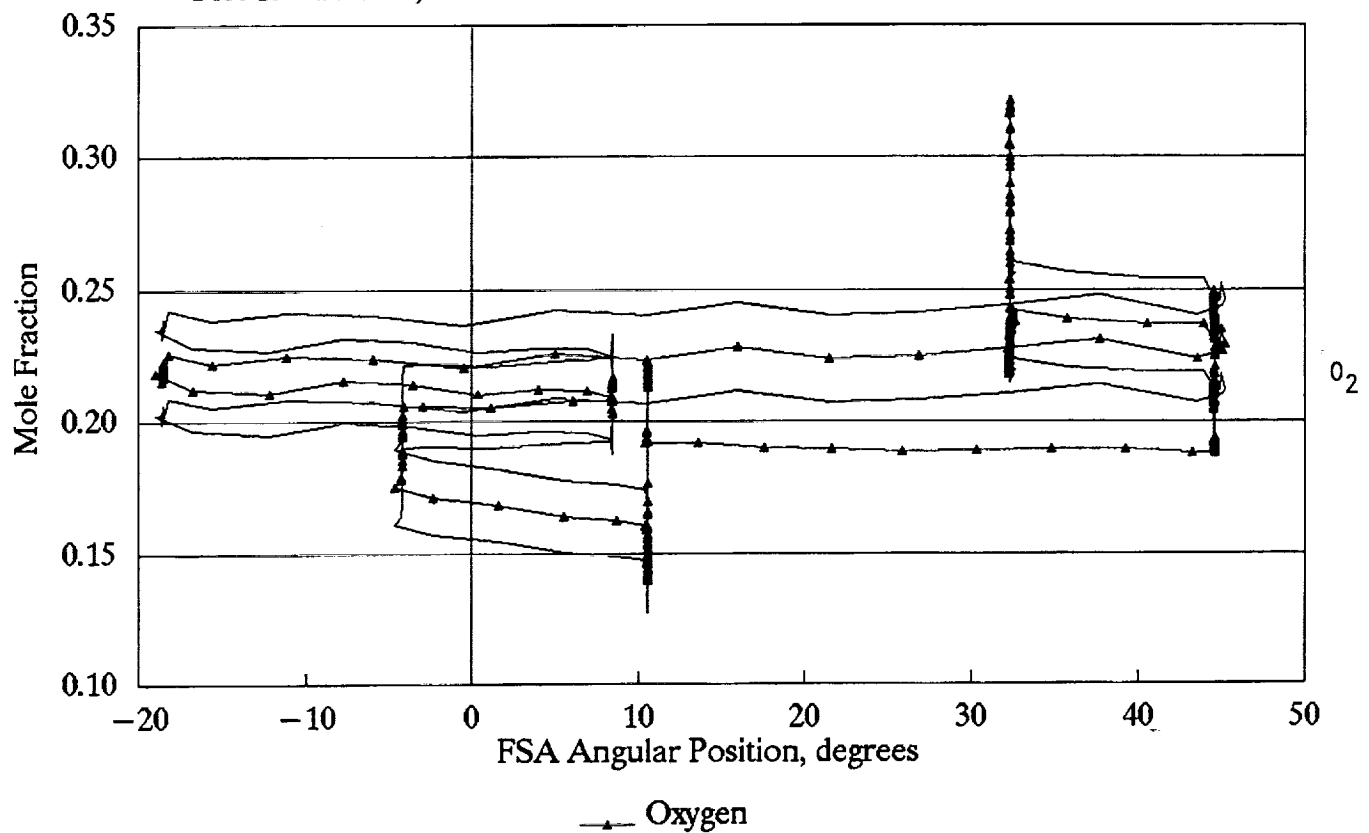
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Nitrogen:	0.510	+/-	0.024
Oxygen:	0.212	+/-	0.018
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.087	+/-	0.008
H2O:	0.174	+/-	0.015
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13⁹ Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

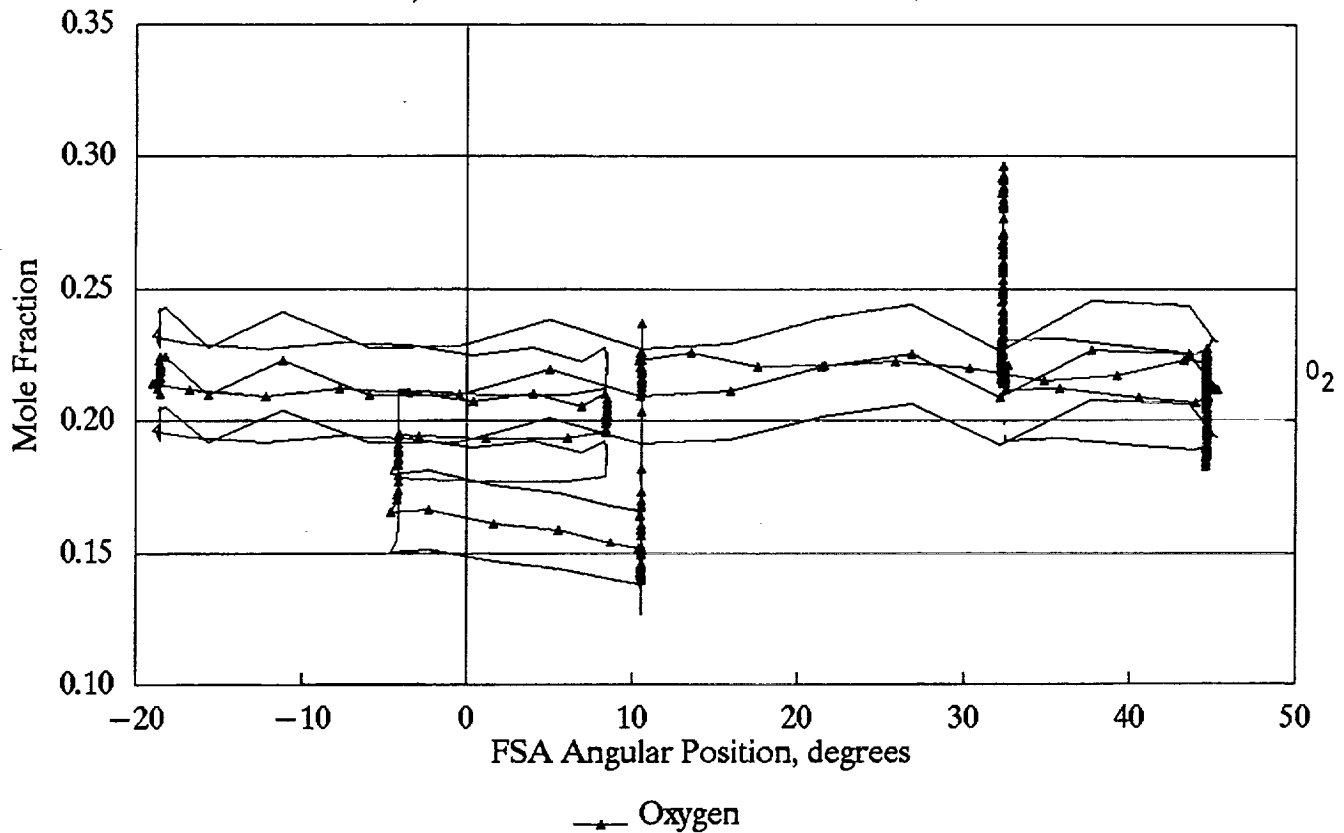
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.218 +/- 0.016

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

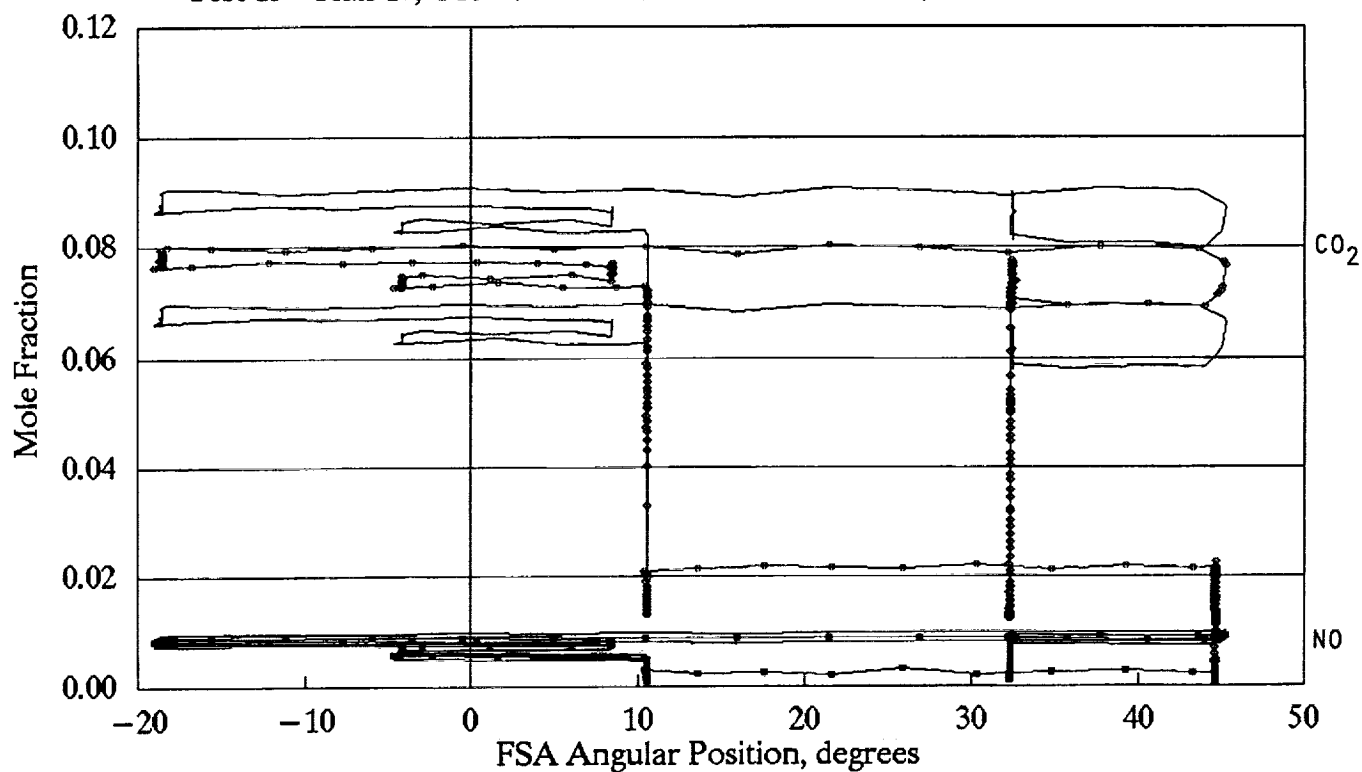
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Oxygen: 0.212 +/- 0.018

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

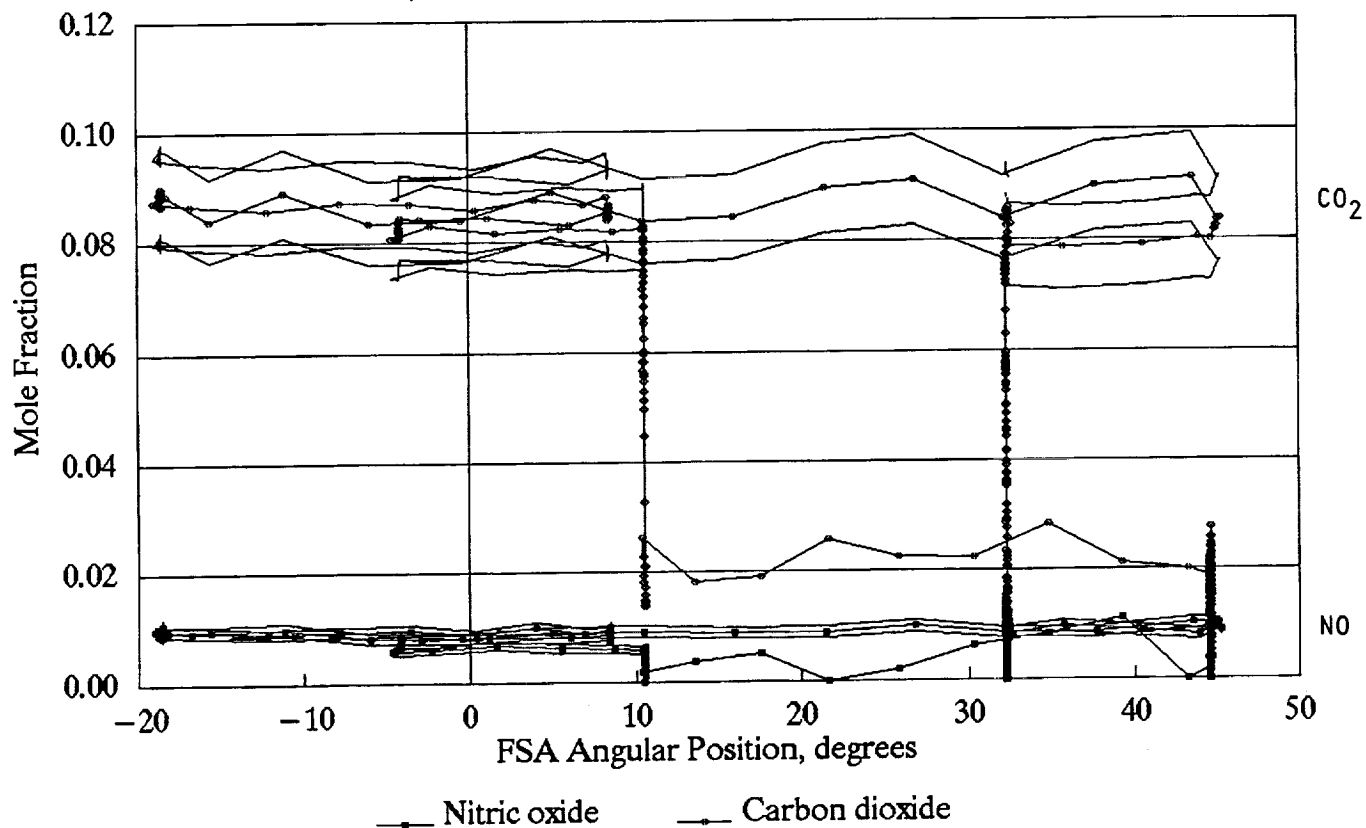
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.078	+/-	0.010
Nitric oxide:	0.008	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

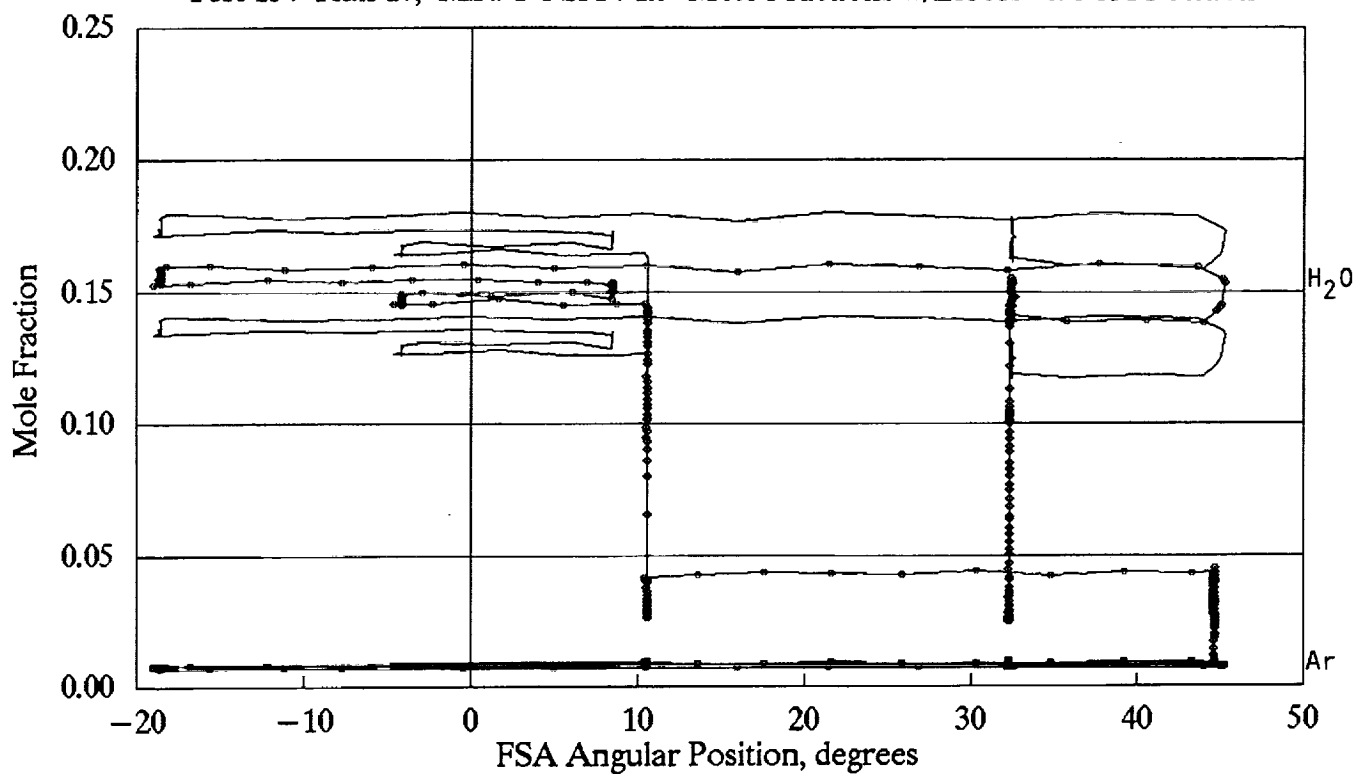
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Carbon dioxide:	0.087	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 17, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



—•— Argon —•— H2O (2*CO2)

Errors given at 95% level of confidence.

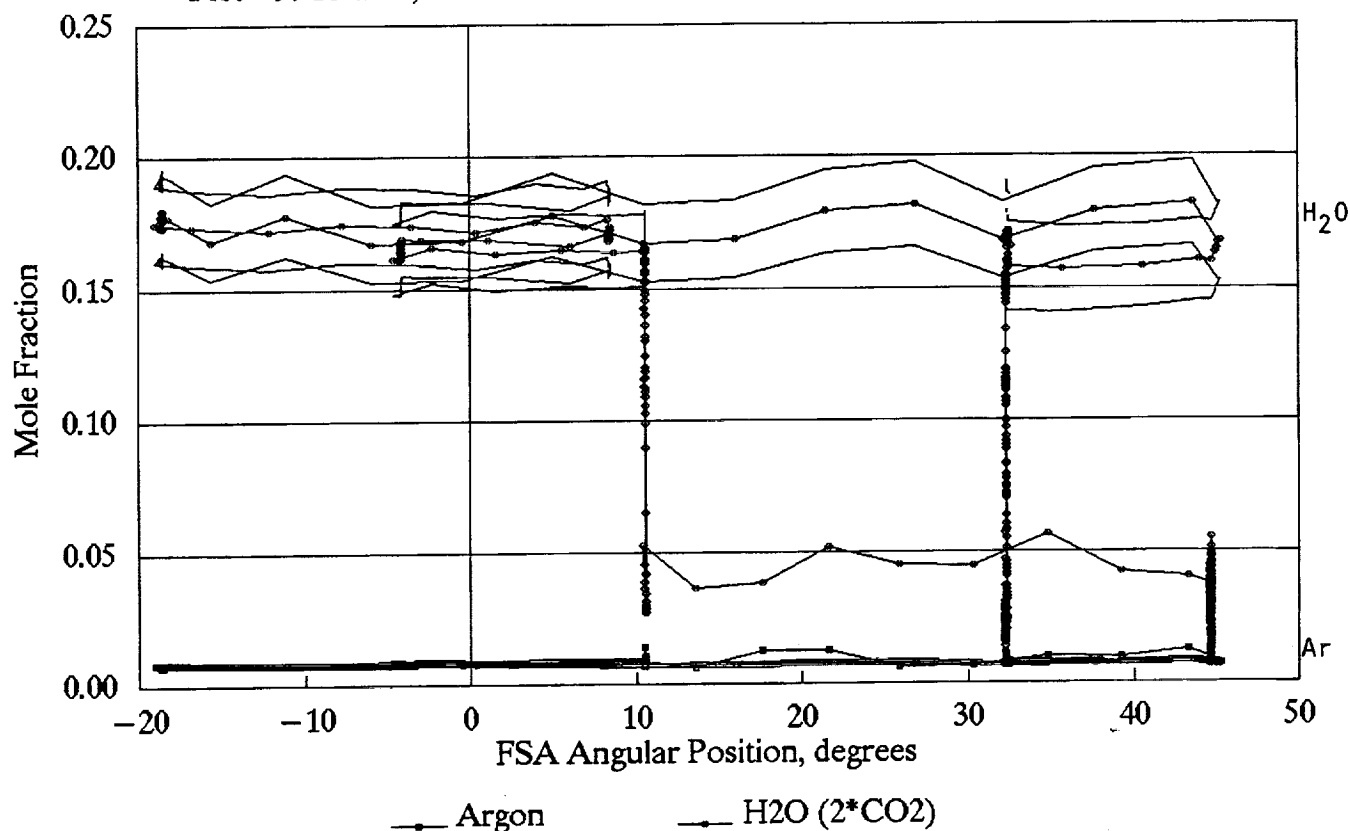
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.155	+/-	0.019

8' HTT Gas Analysis System

Test 139 Run 17, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 140 to 150 seconds:

Argon:	0.008	+/-	0.001
H ₂ O:	0.174	+/-	0.015

Test 139 Run 18

Combustor Pressure: 1000 psia

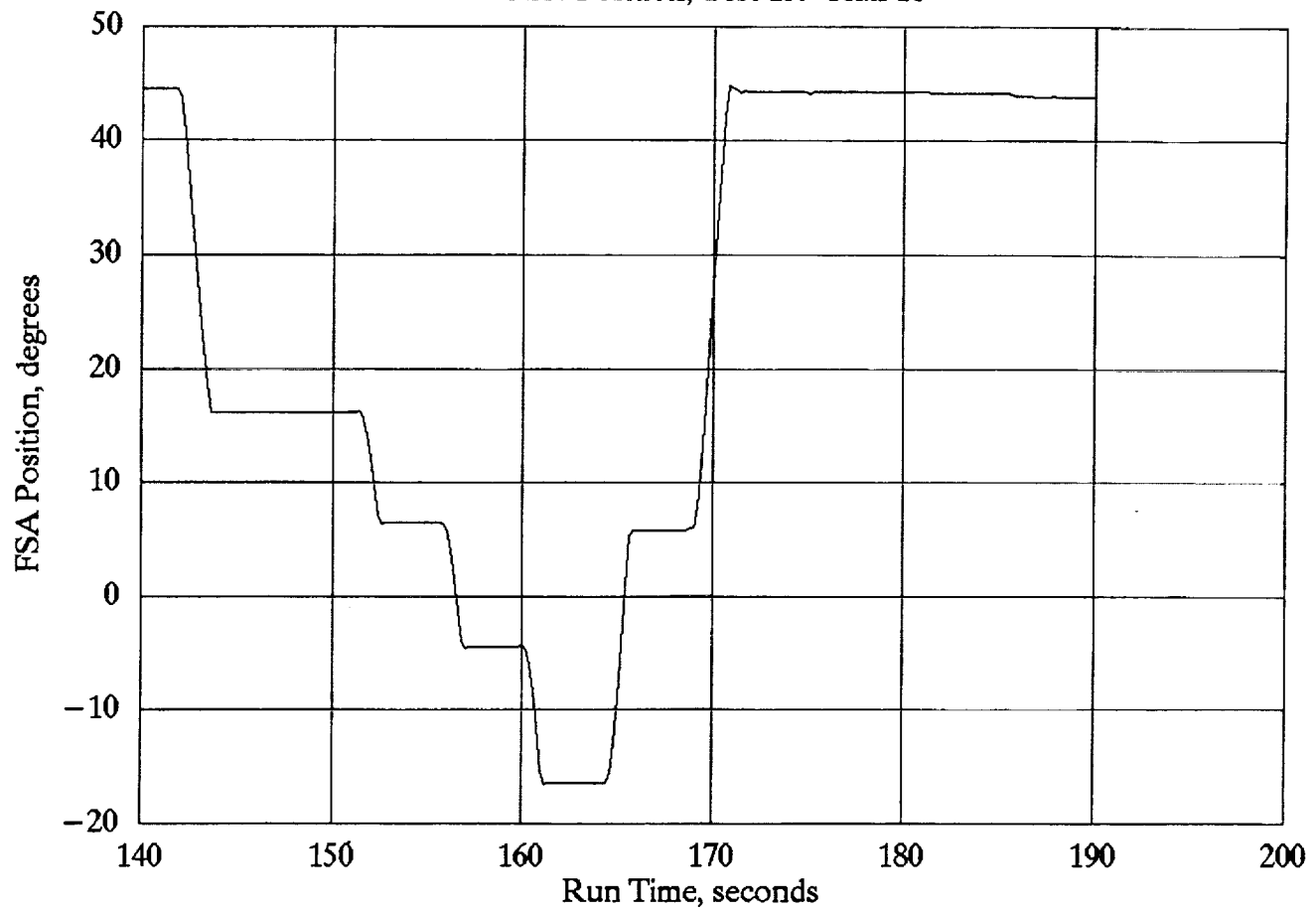
Combustor Temperature: 3400 R

Normal Stop: 170.1 seconds

Probes: FSA+1.5

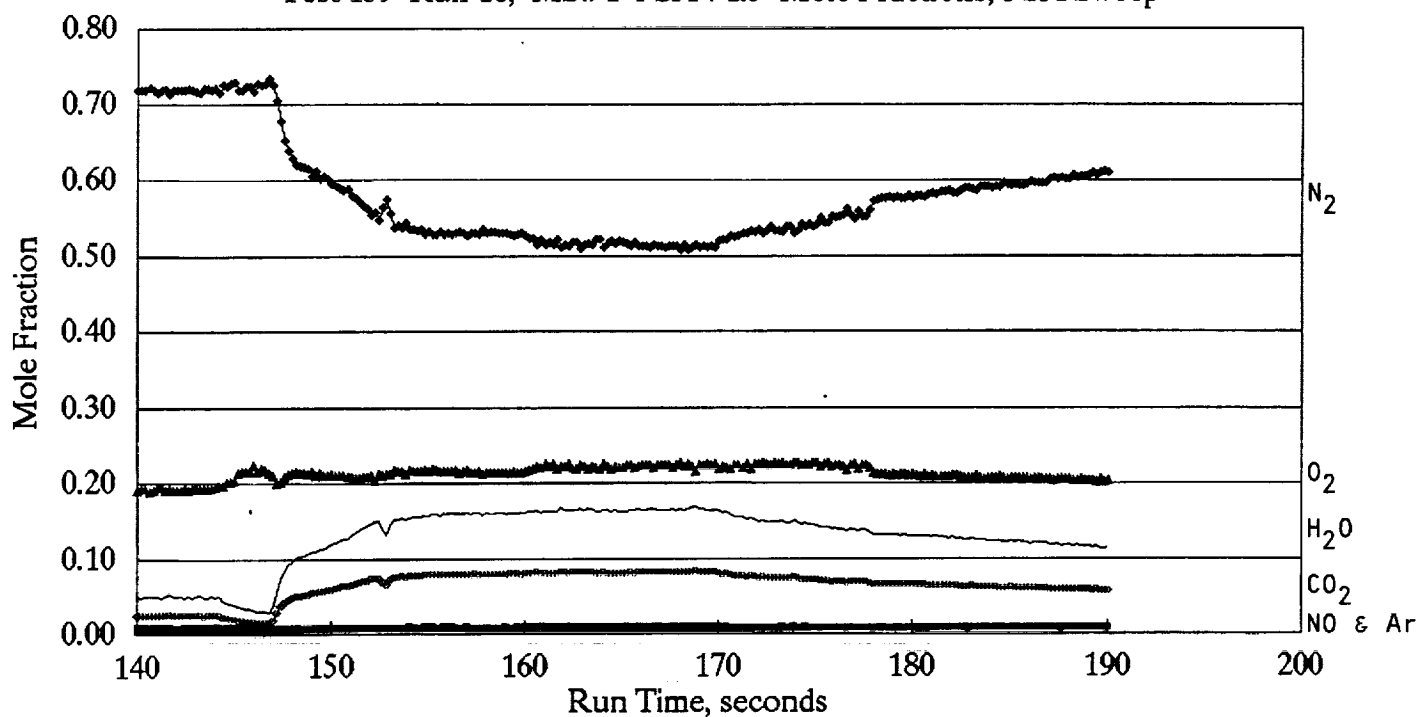
8' HTT Gas Analysis System

FSA Position, Test 139 Run 18



8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H₂O (2*CO₂)

Sum of mole fractions = 1.

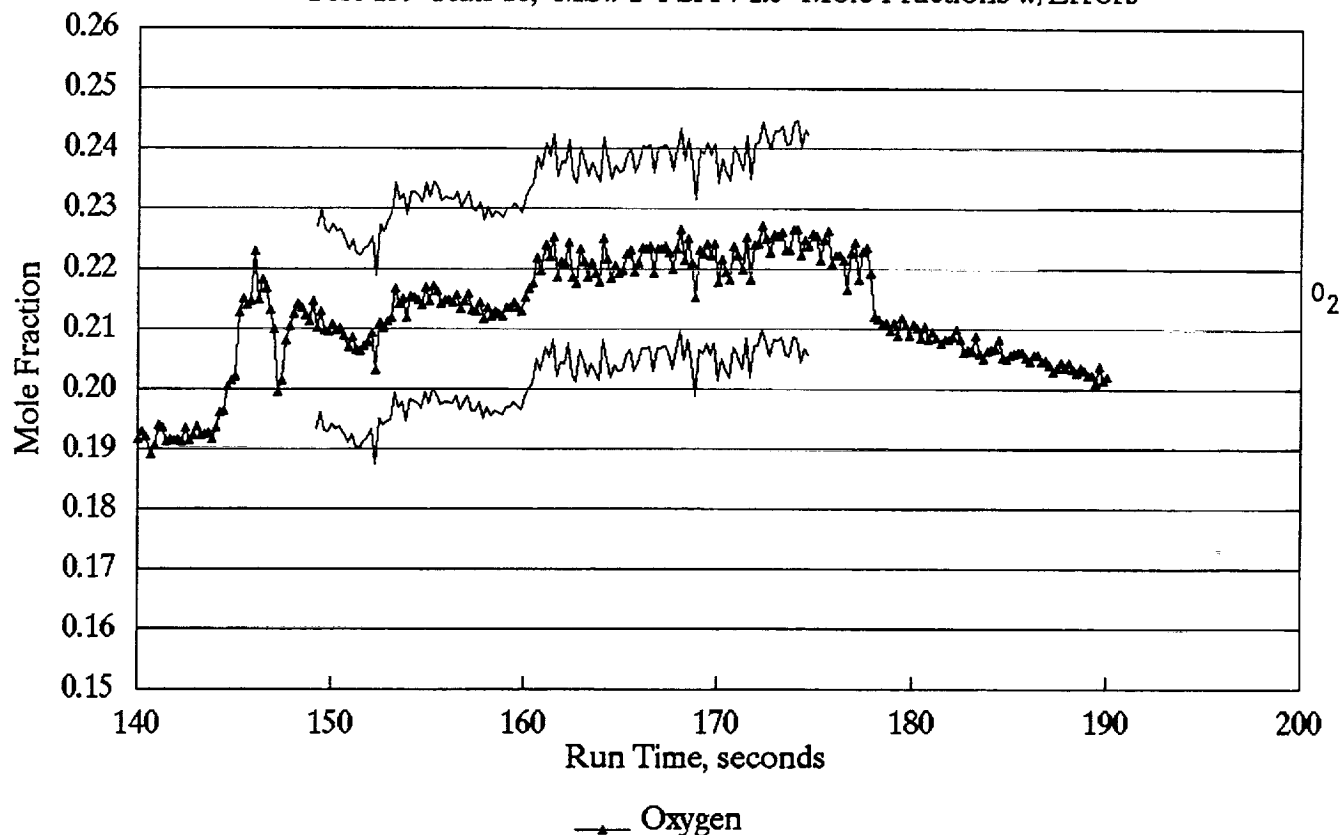
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.521	+/-	0.024
Oxygen:	0.219	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.011
H ₂ O:	0.162	+/-	0.021
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

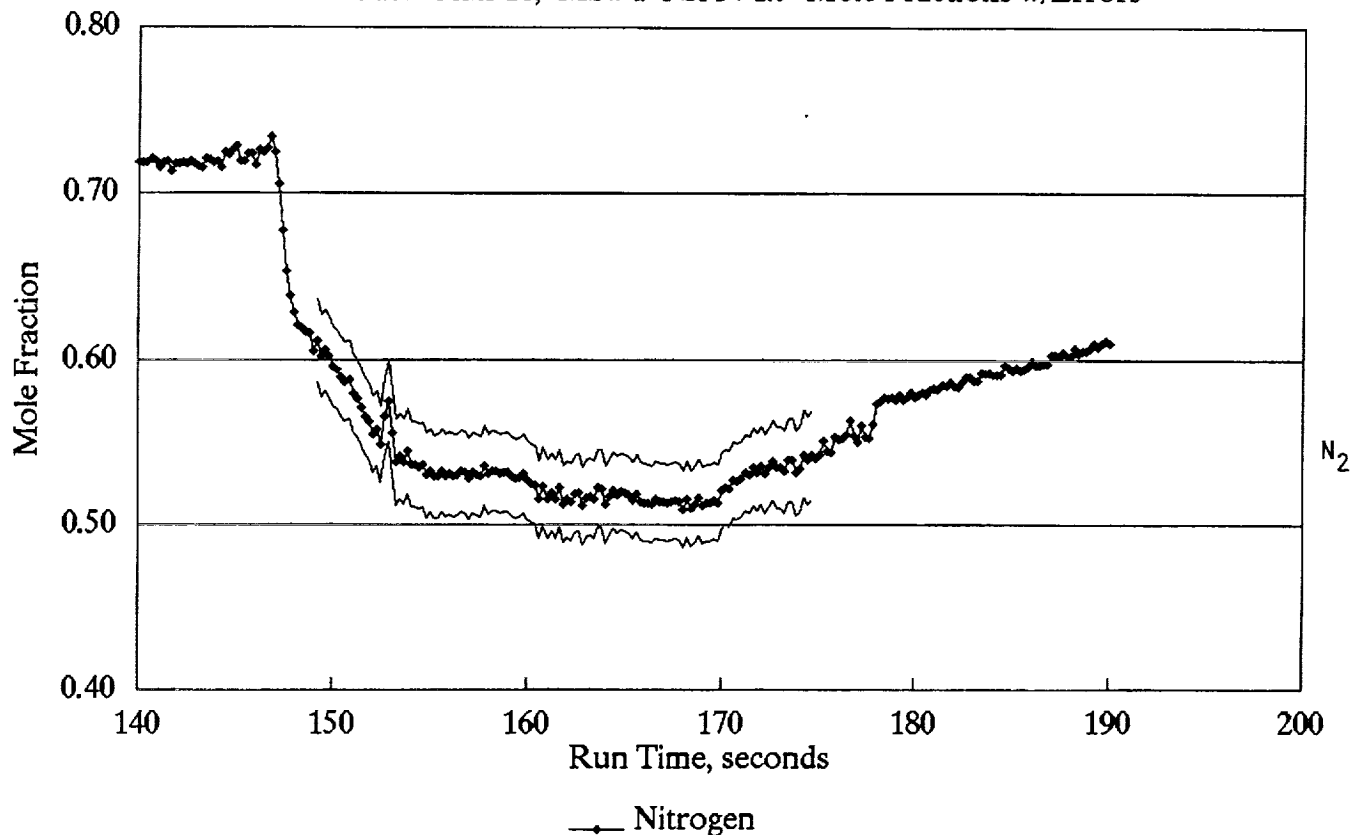
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.219 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

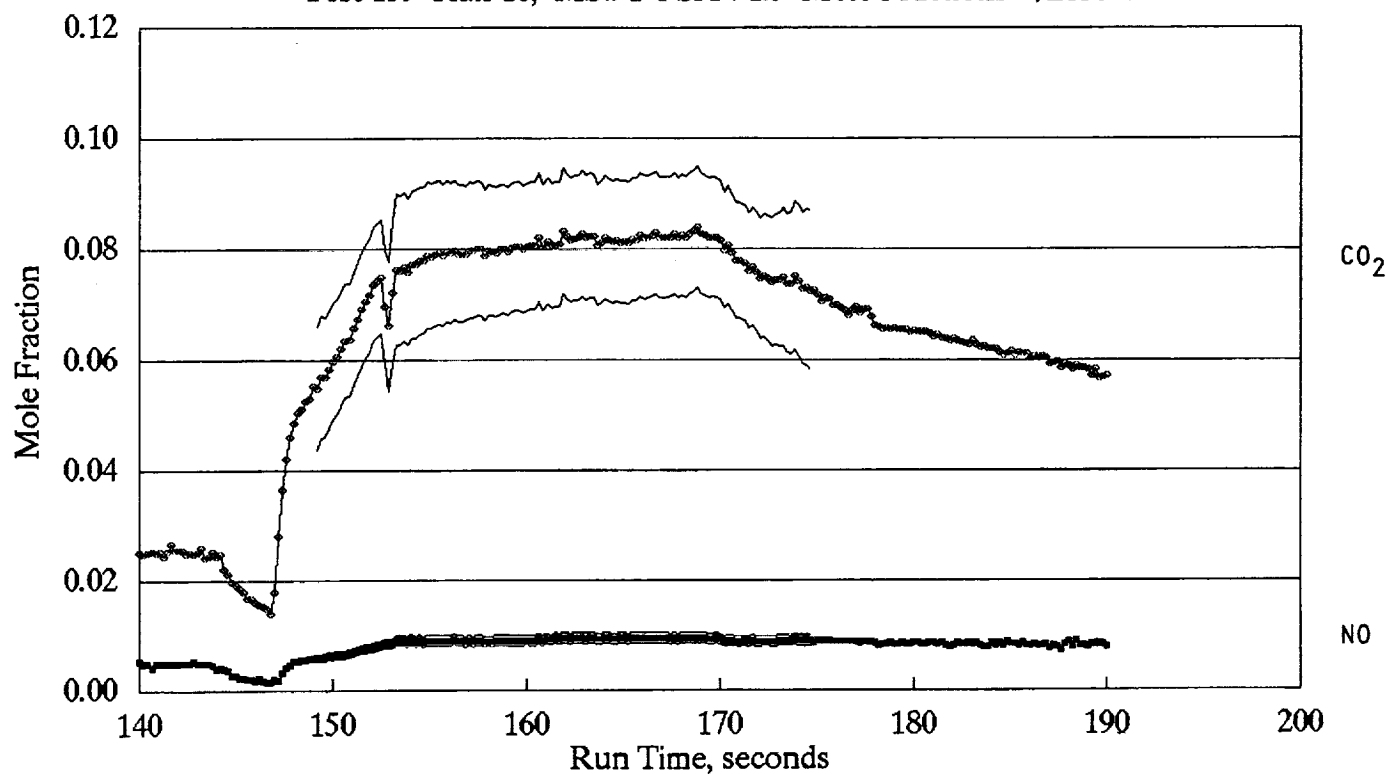
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen: 0.521 +/- 0.024

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

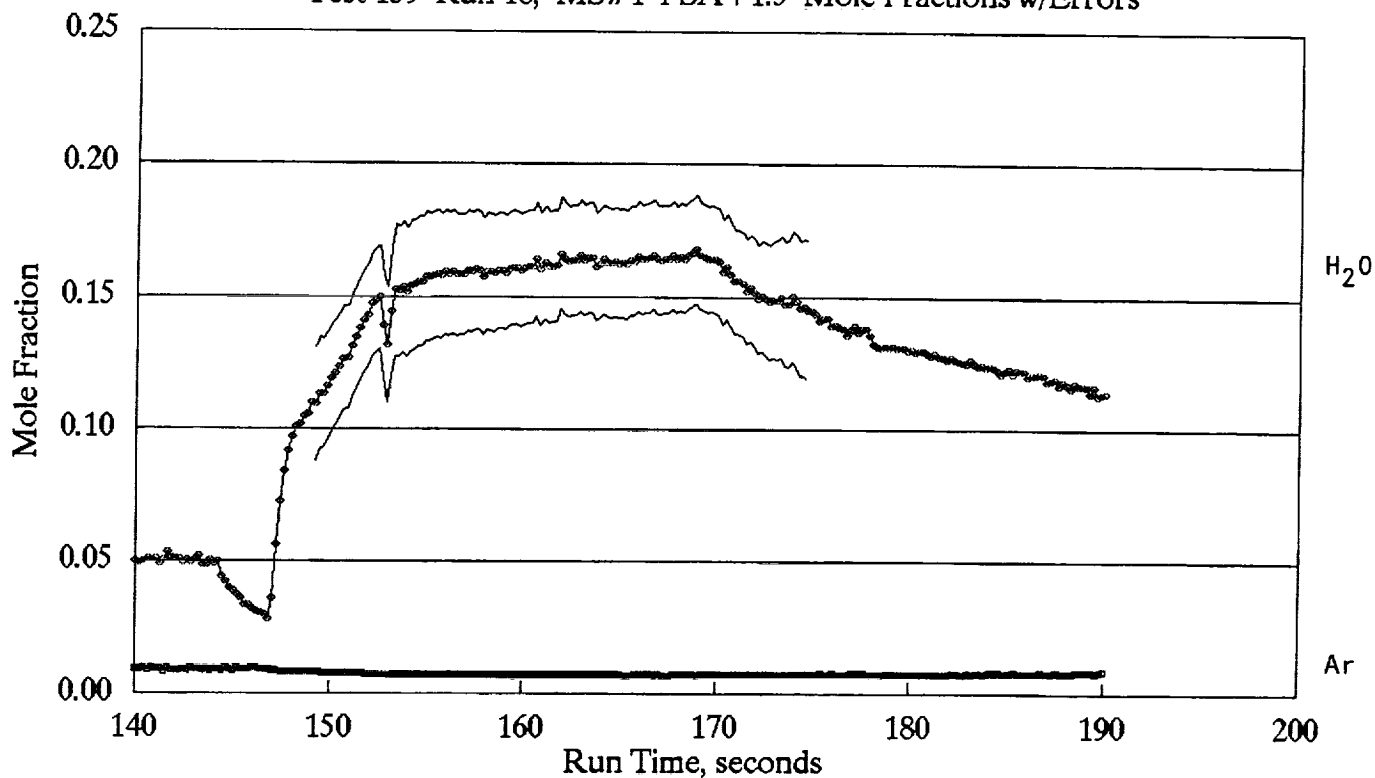
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.081	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors



—•— Argon —•— H2O (2*CO2)

Errors given at 95% level of confidence.

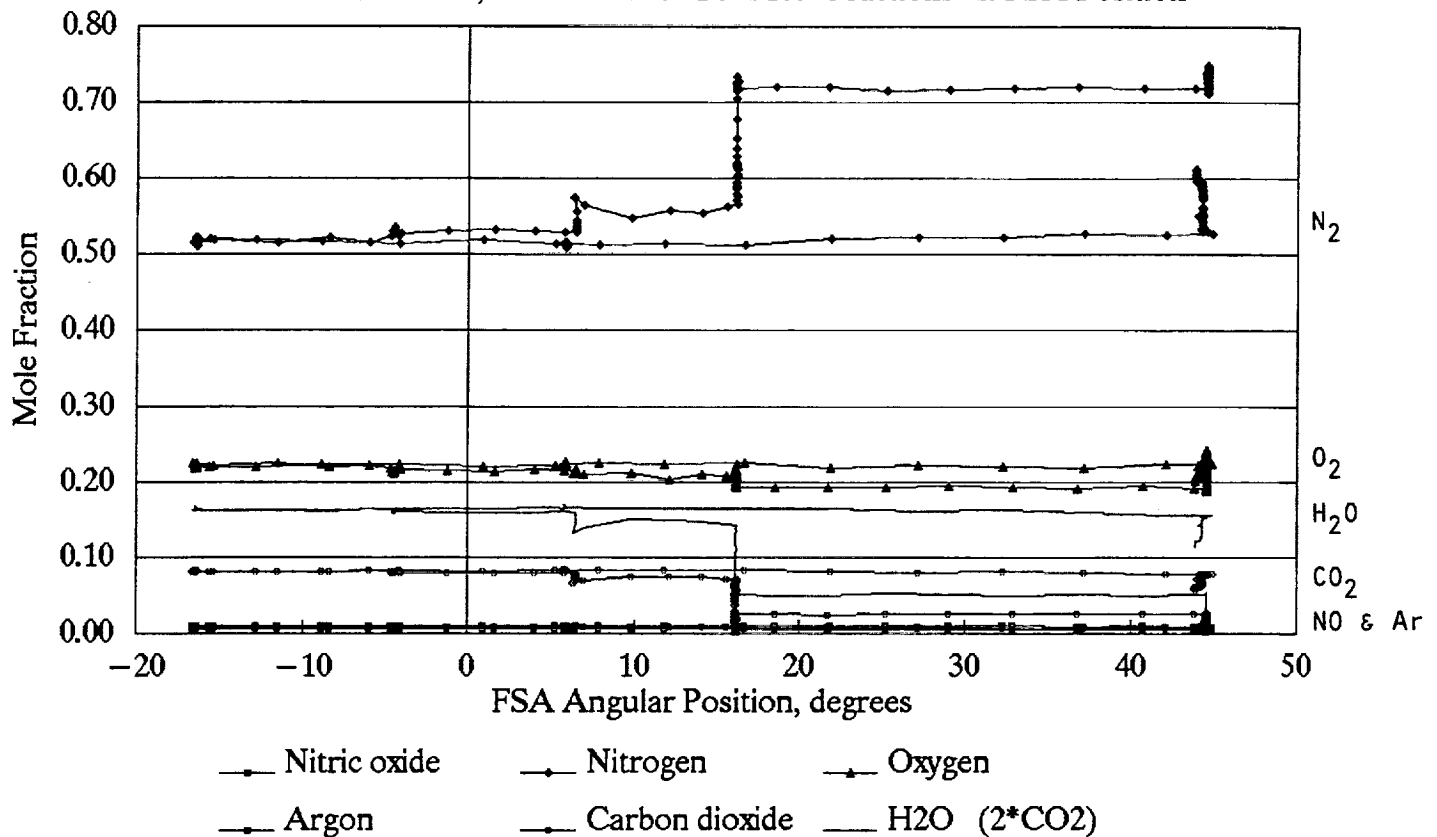
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.021

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



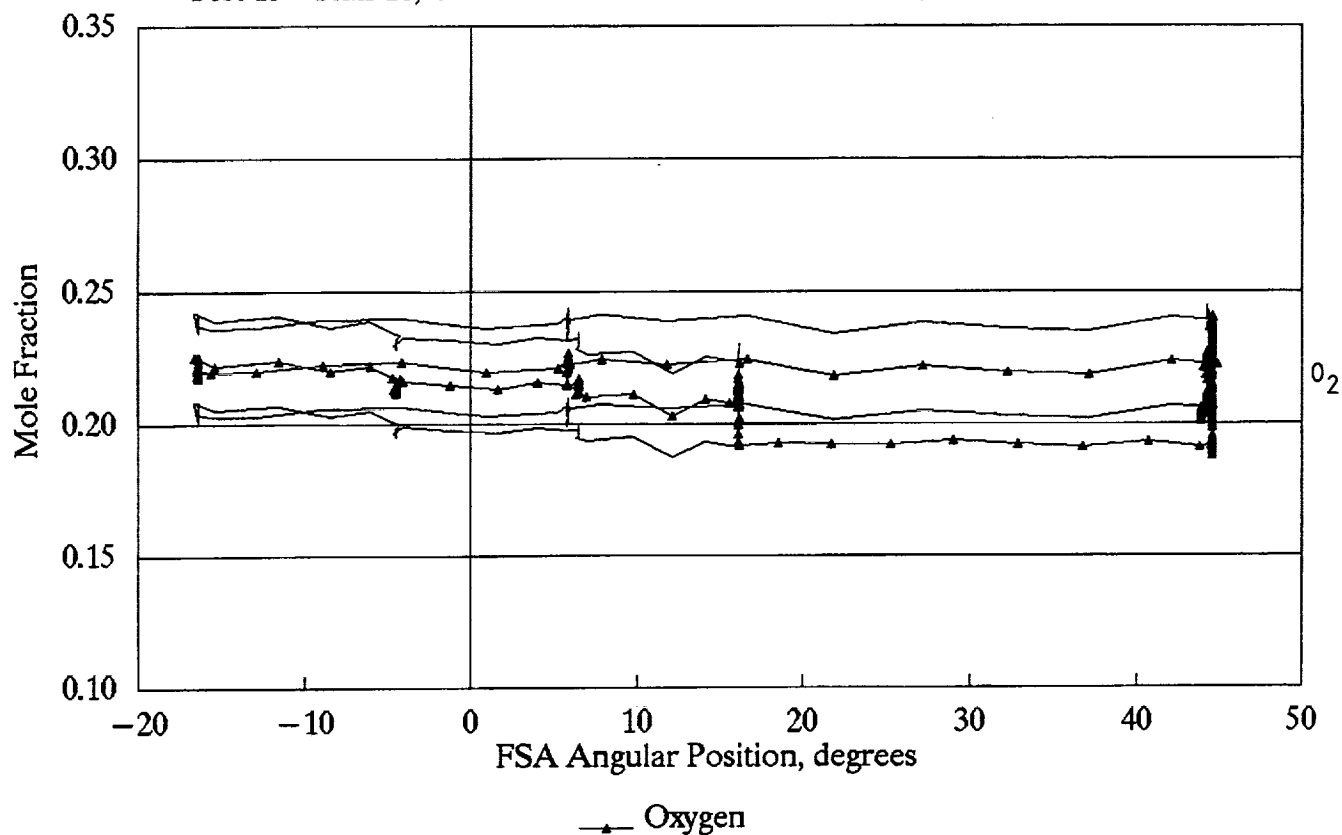
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.521	+/-	0.024
Oxygen:	0.219	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.011
H2O:	0.162	+/-	0.021
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

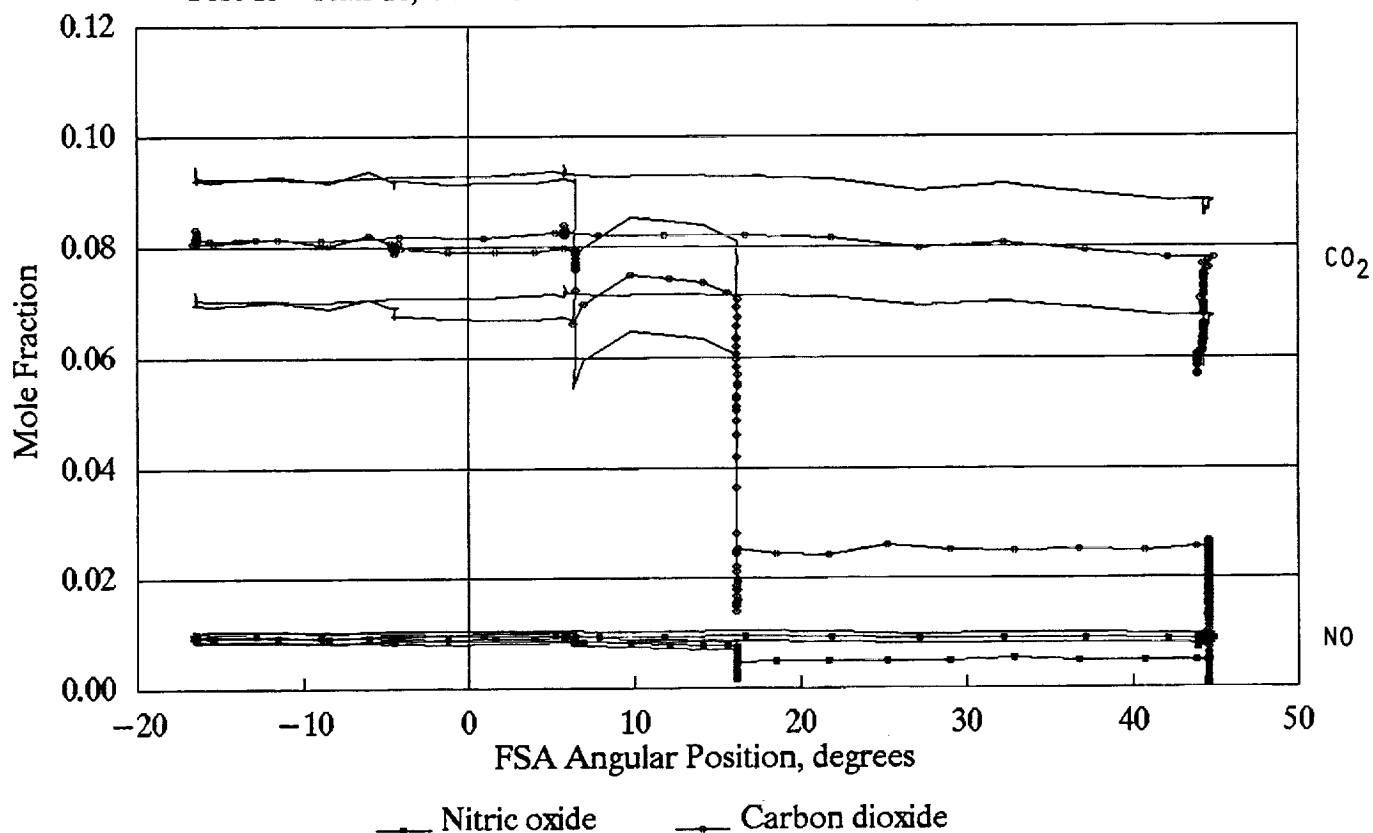
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.219 +/- 0.017

8' HTT Gas Analysis System

Test 13⁹ Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

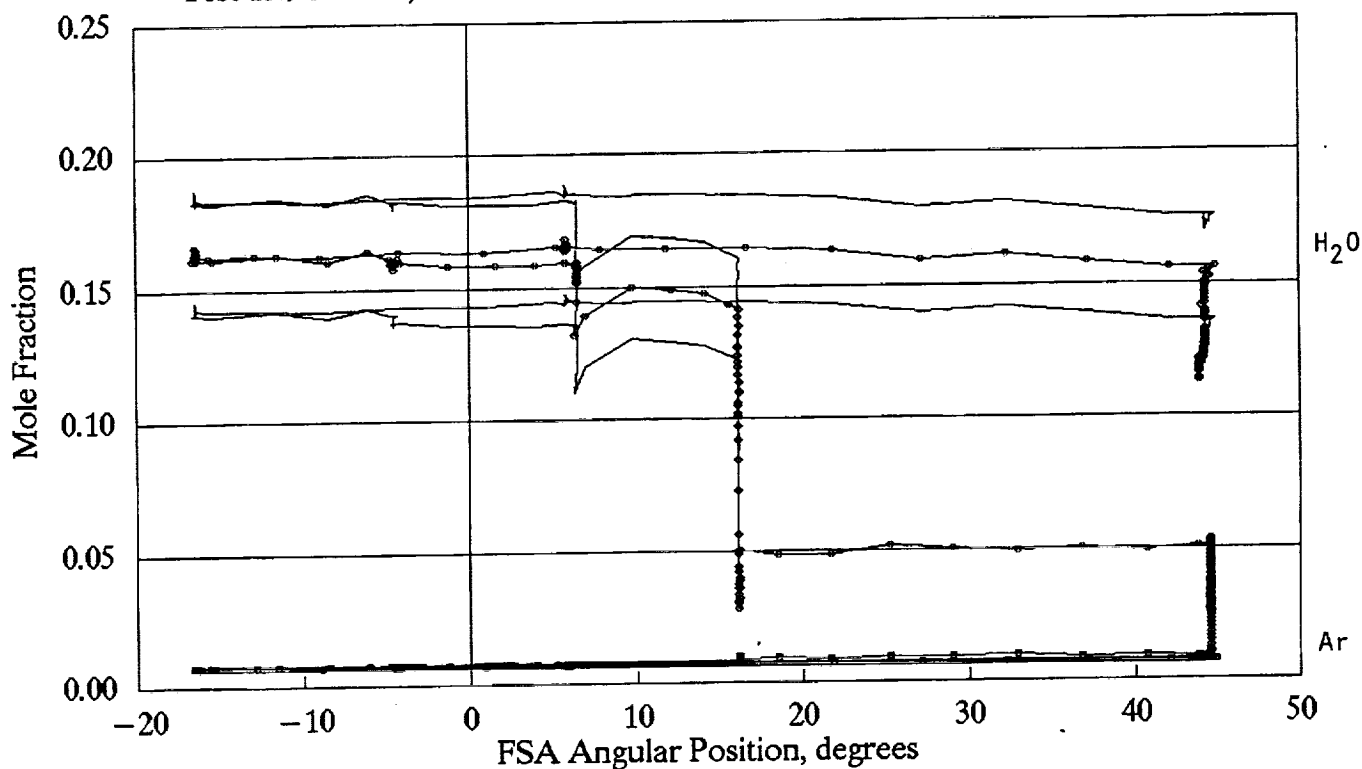
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.081	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13.9 Run 18, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



— Argon

— H2O (2*CO2)

Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.162	+/-	0.021

Test 139 Run 19

Combustor Pressure: 1000 psia

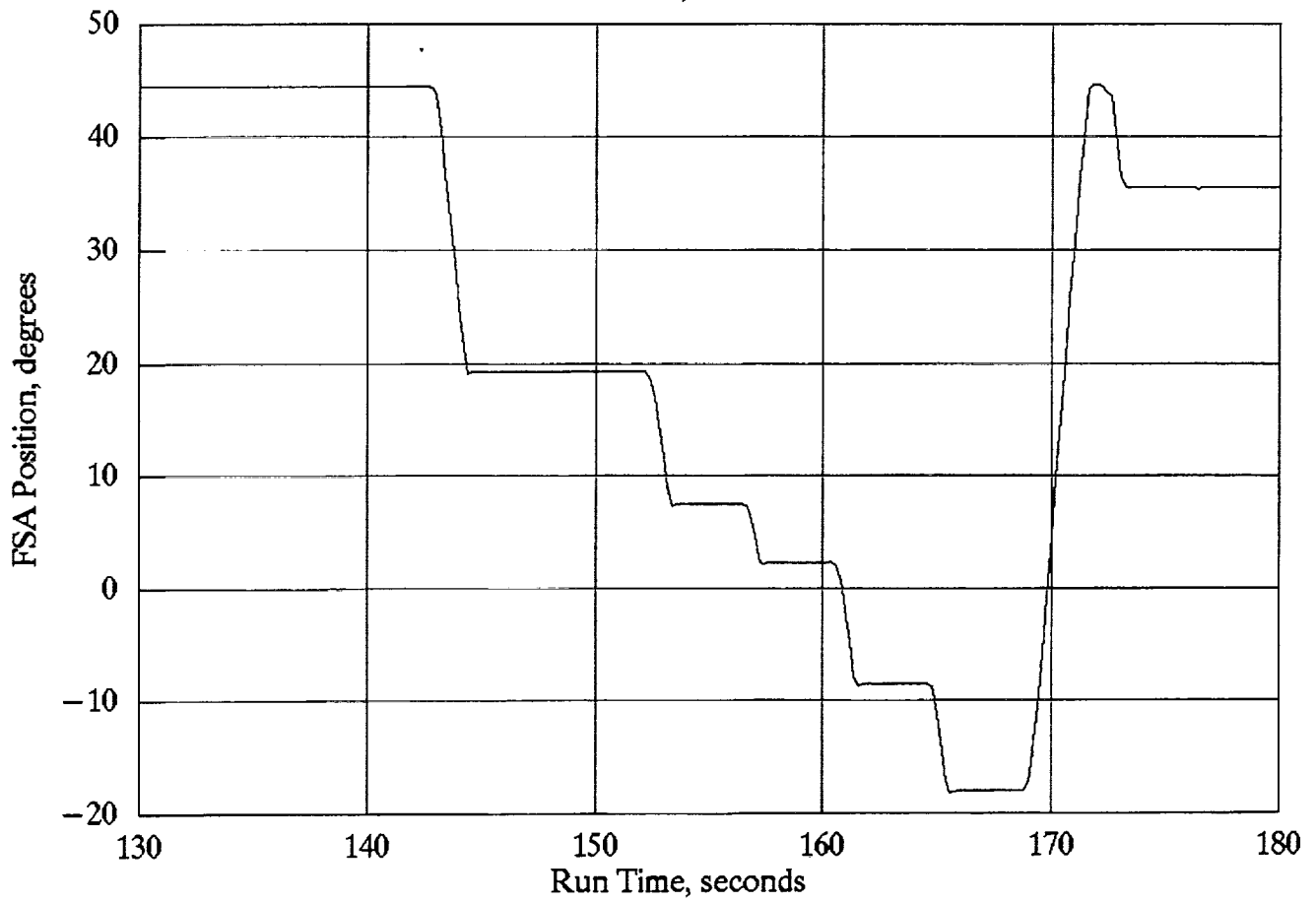
Combustor Temperature: 3400 R

Normal Stop: 170.1 seconds

Probes: FSA+1.5, FSA-1.5

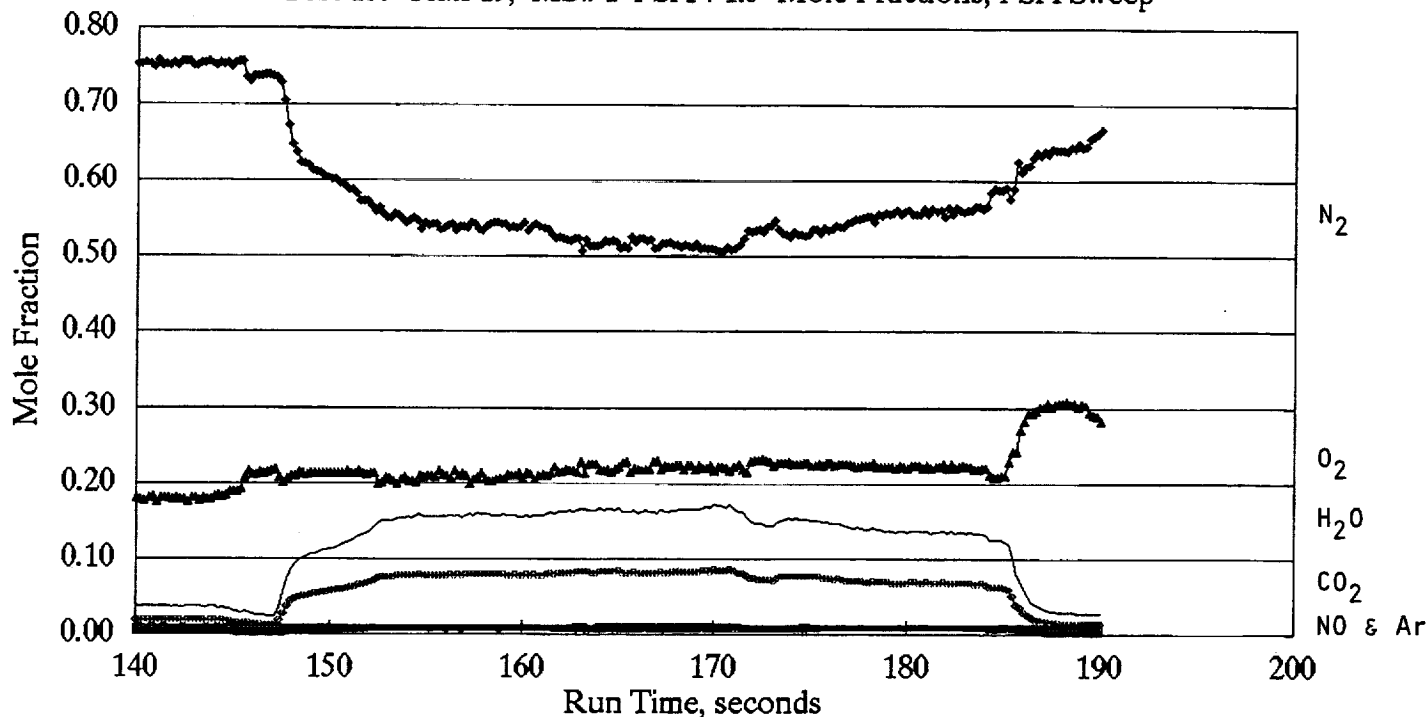
8' HTT Gas Analysis System

FSA Position, Test 139 Run 19



8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

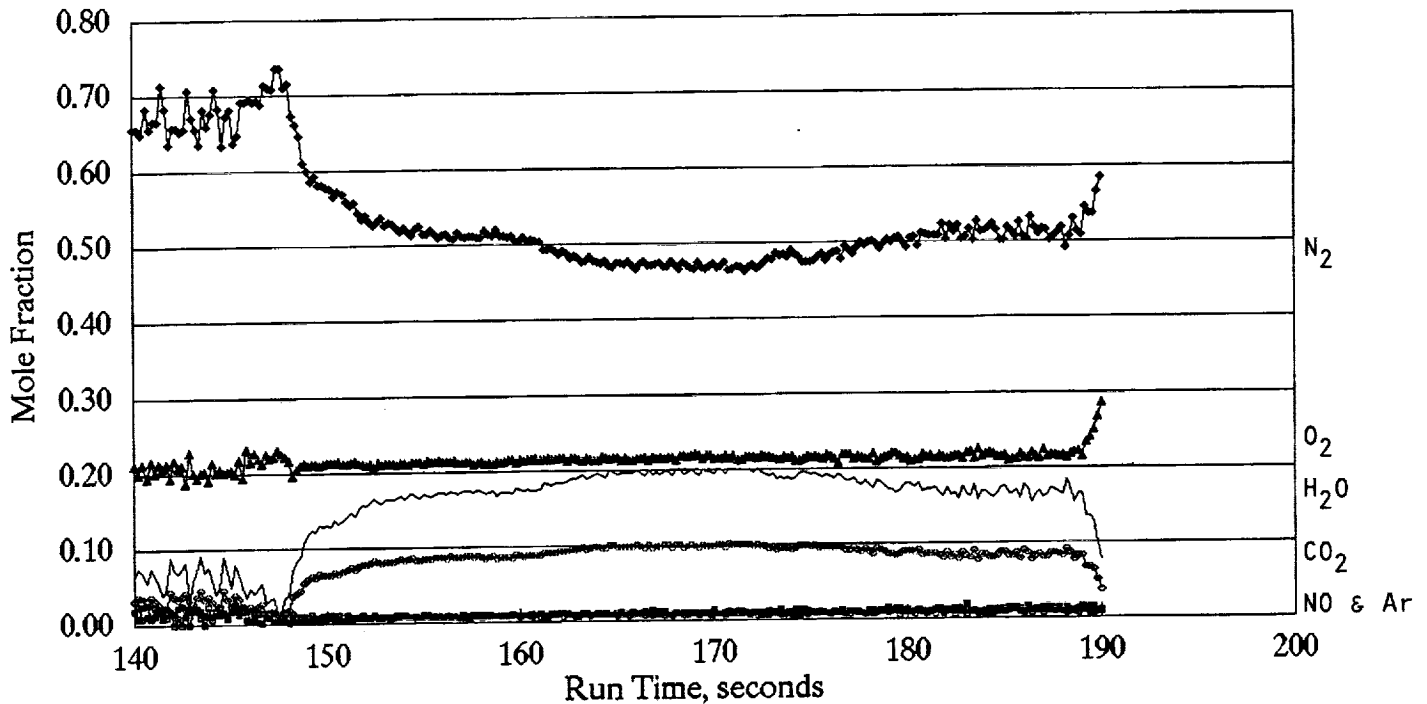
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.527	+/-	0.026
Oxygen:	0.215	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.011
H2O:	0.161	+/-	0.021
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions, FSA Sweep



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

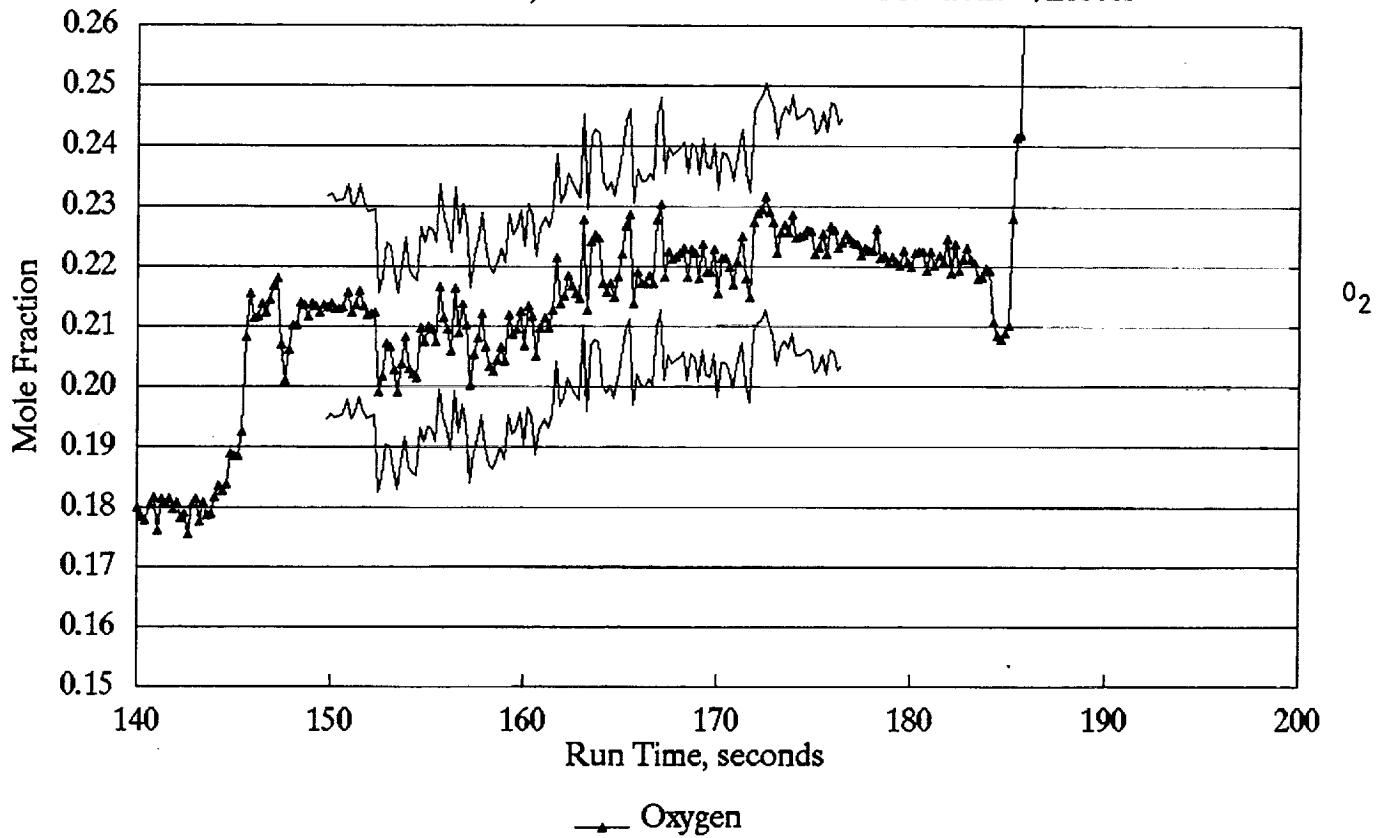
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.491	+/-	0.021
Oxygen:	0.214	+/-	0.015
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.093	+/-	0.008
H2O:	0.185	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

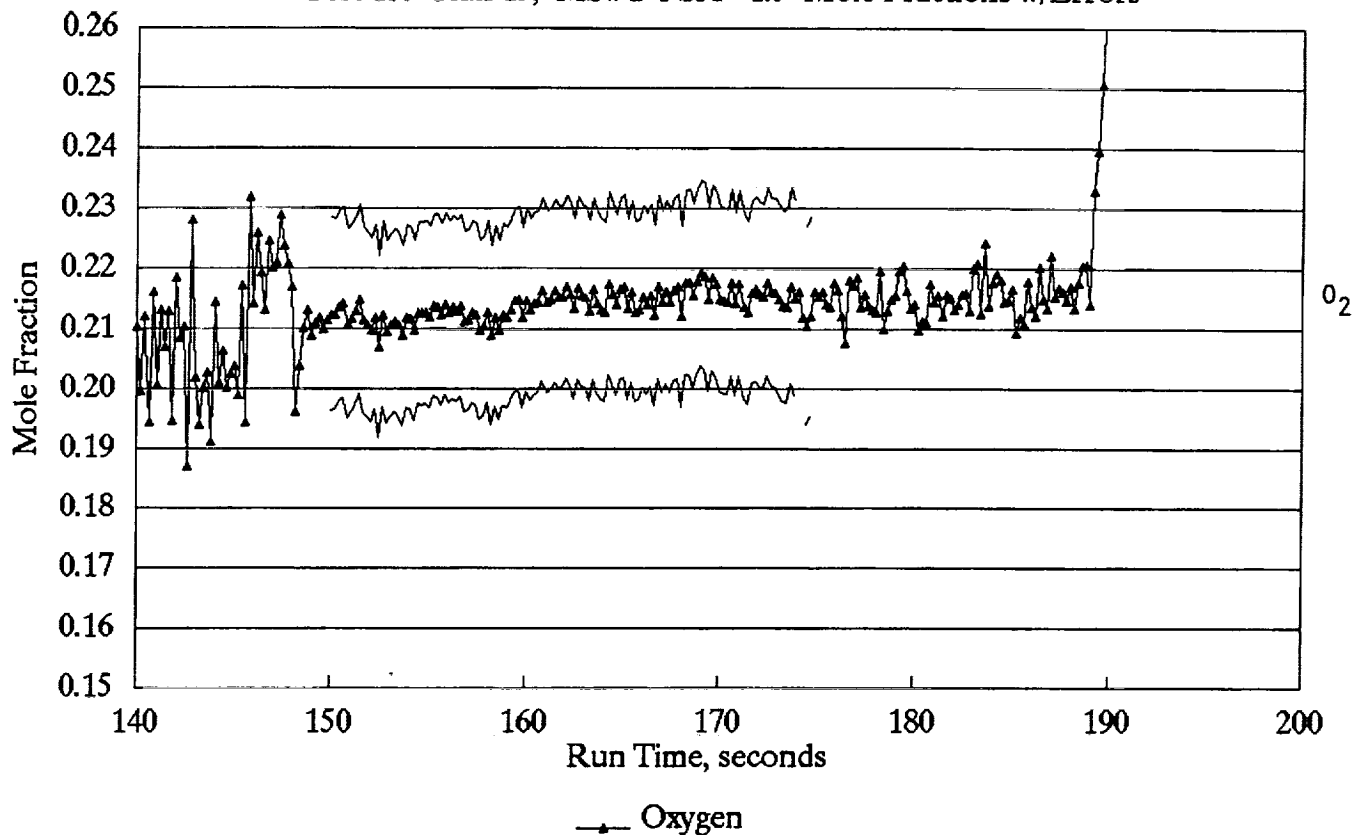
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.215 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

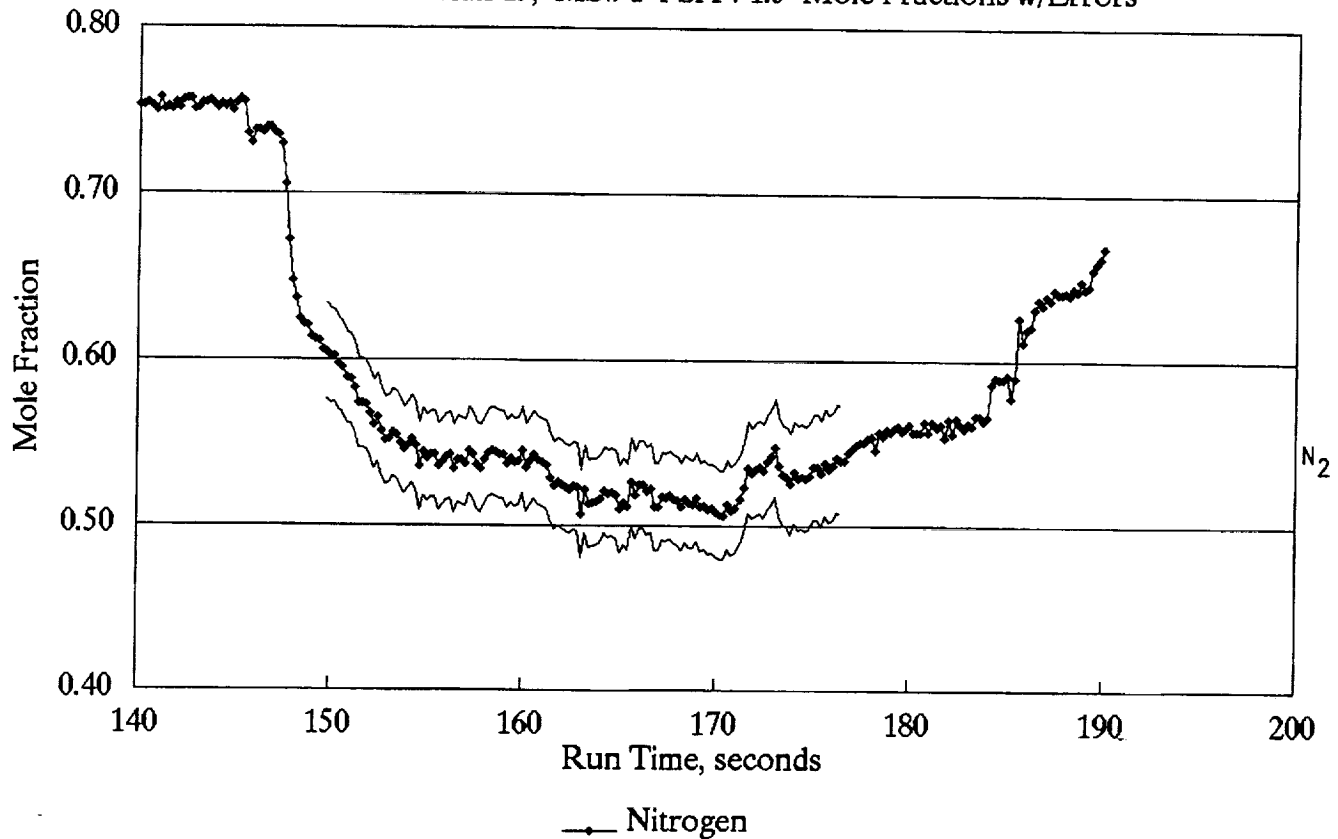
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.214 +/- 0.015

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

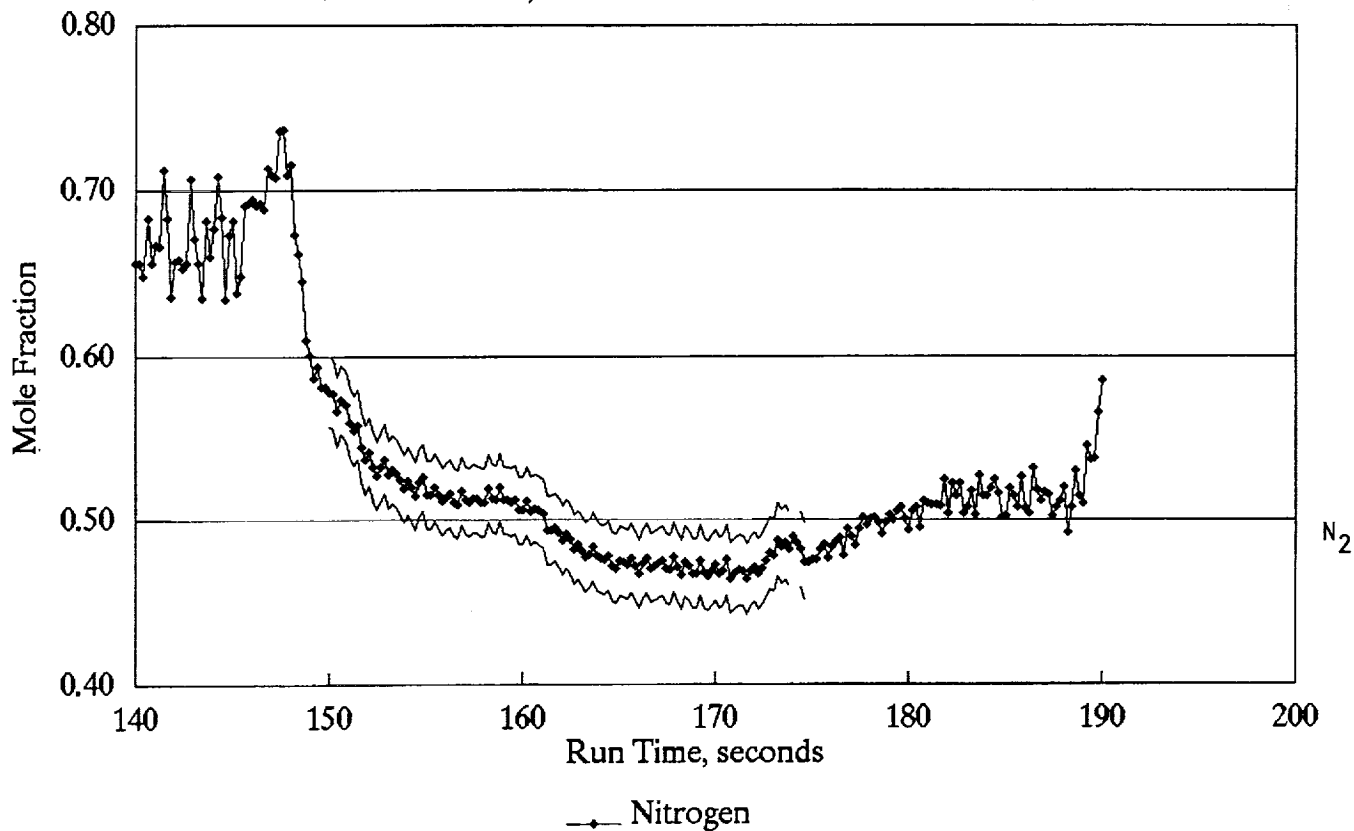
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen: 0.527 +/- 0.026

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

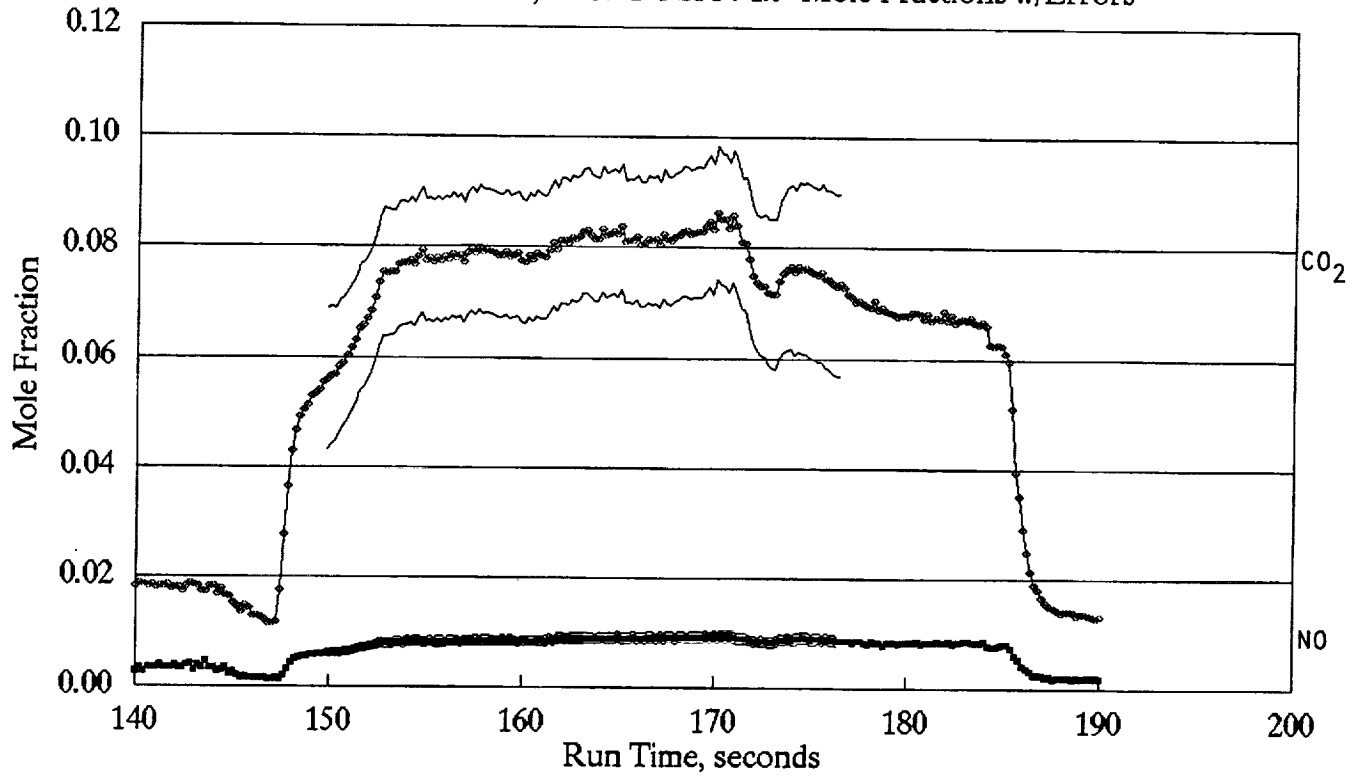
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen: 0.491 +/- 0.021

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors



— Nitric oxide — Carbon dioxide

Errors given at 95% level of confidence.

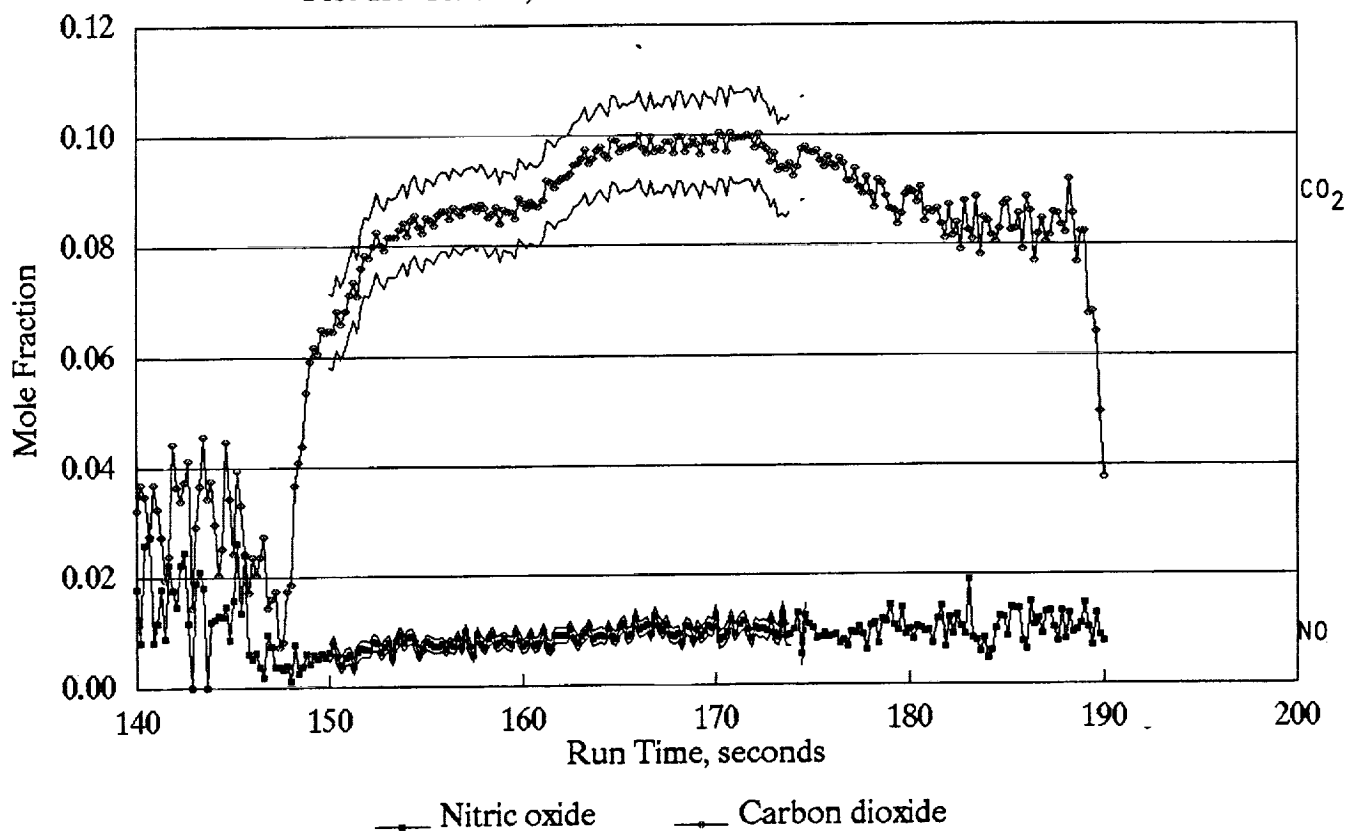
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.081	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

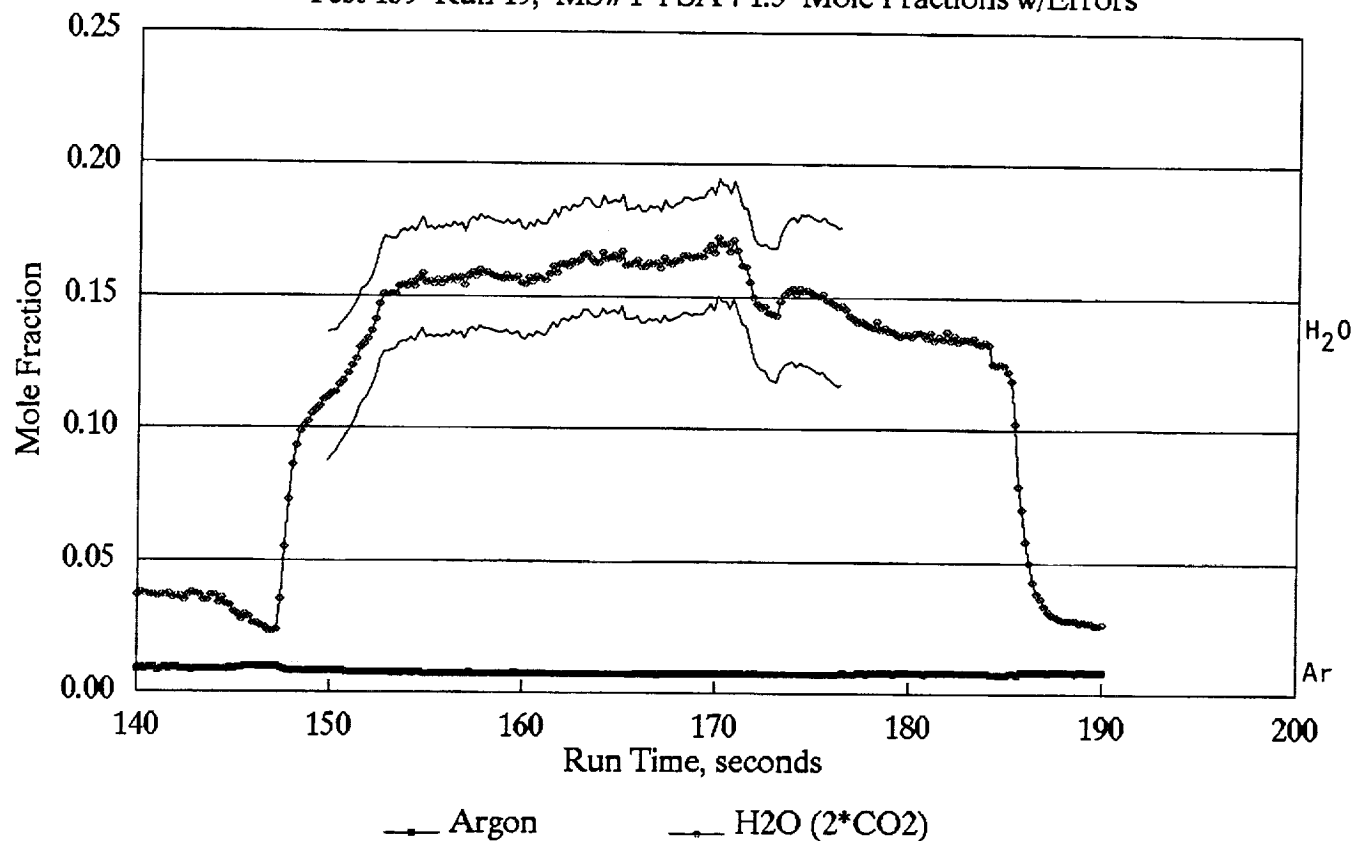
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.093	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors



Errors given at 95% level of confidence.

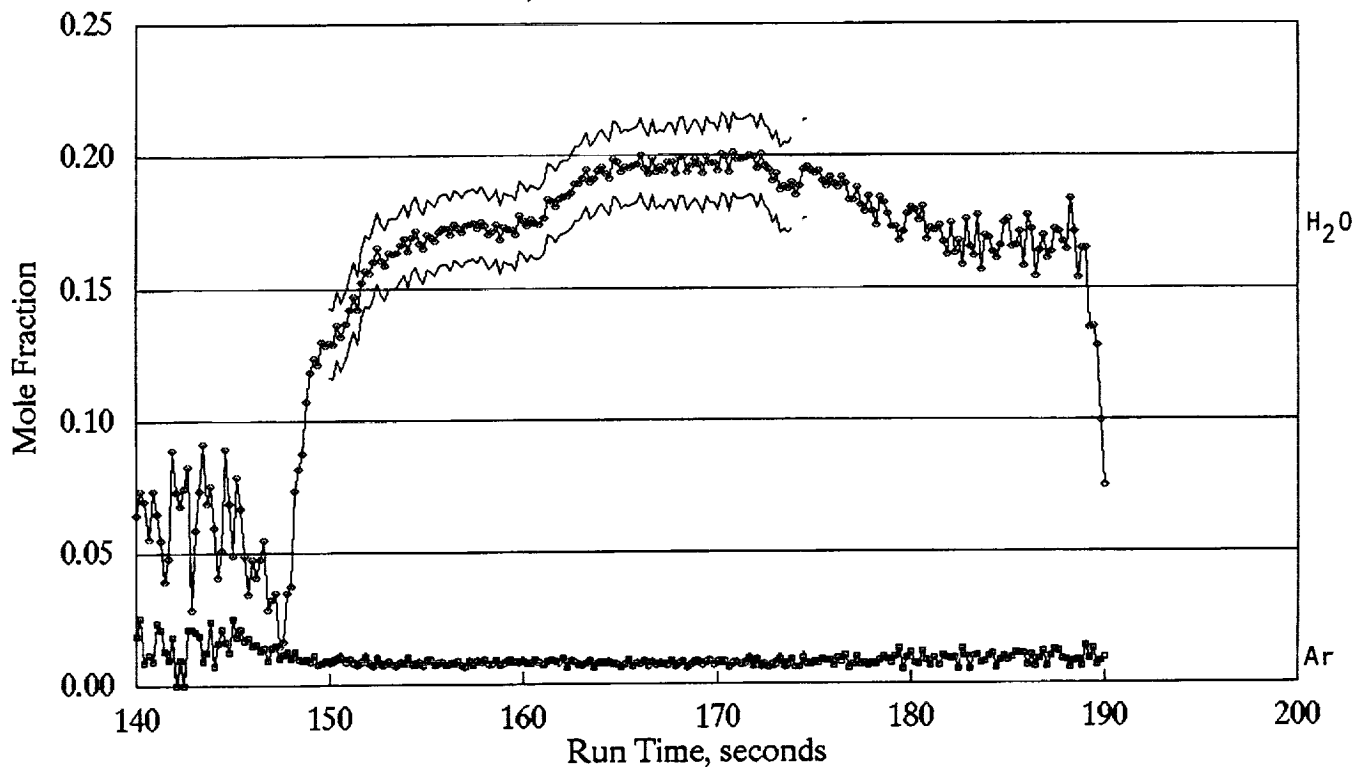
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.007	+/-	0.001
H ₂ O:	0.161	+/-	0.021

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors



— Argon — H₂O (2*CO₂)

Errors given at 95% level of confidence.

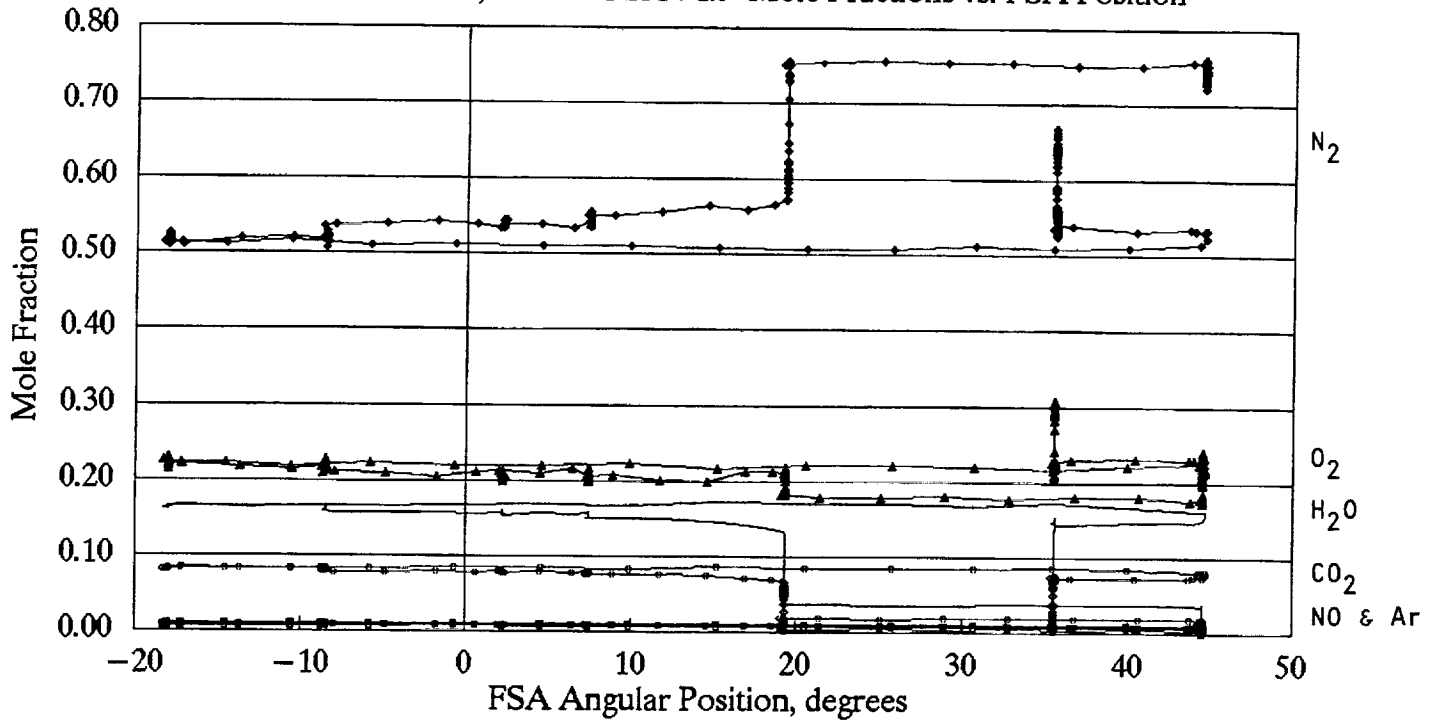
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.008	+/-	0.001
H ₂ O:	0.185	+/-	0.014

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions vs. FSA Position



— Nitric oxide — Nitrogen — Oxygen
 — Argon — Carbon dioxide — H2O (2*CO2)

Sum of mole fractions = 1.

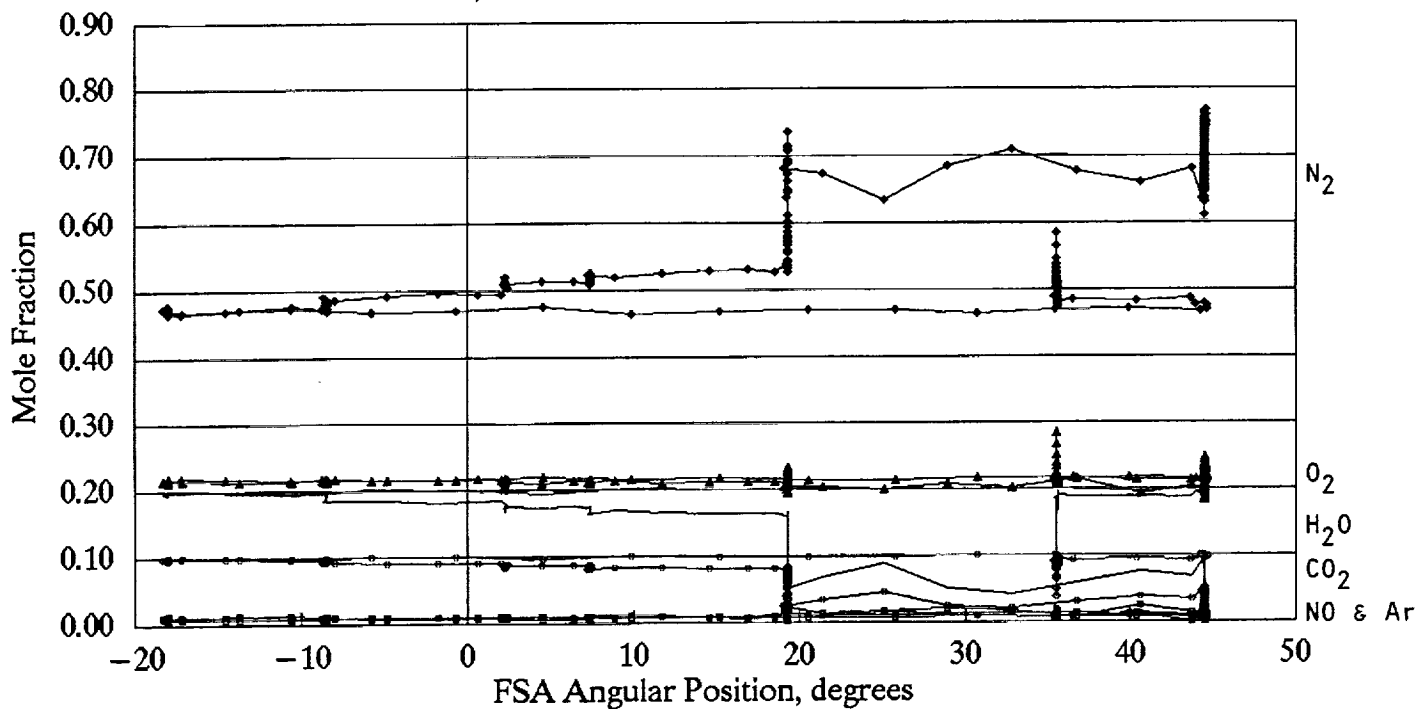
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.527	+/-	0.026
Oxygen:	0.215	+/-	0.017
Argon:	0.007	+/-	0.001
Carbon dioxide:	0.081	+/-	0.011
H2O:	0.161	+/-	0.021
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions vs. FSA Position



—●— Nitric oxide —■— Nitrogen —▲— Oxygen
 —○— Argon —×— Carbon dioxide —+— H2O (2*CO2)

Sum of mole fractions = 1.

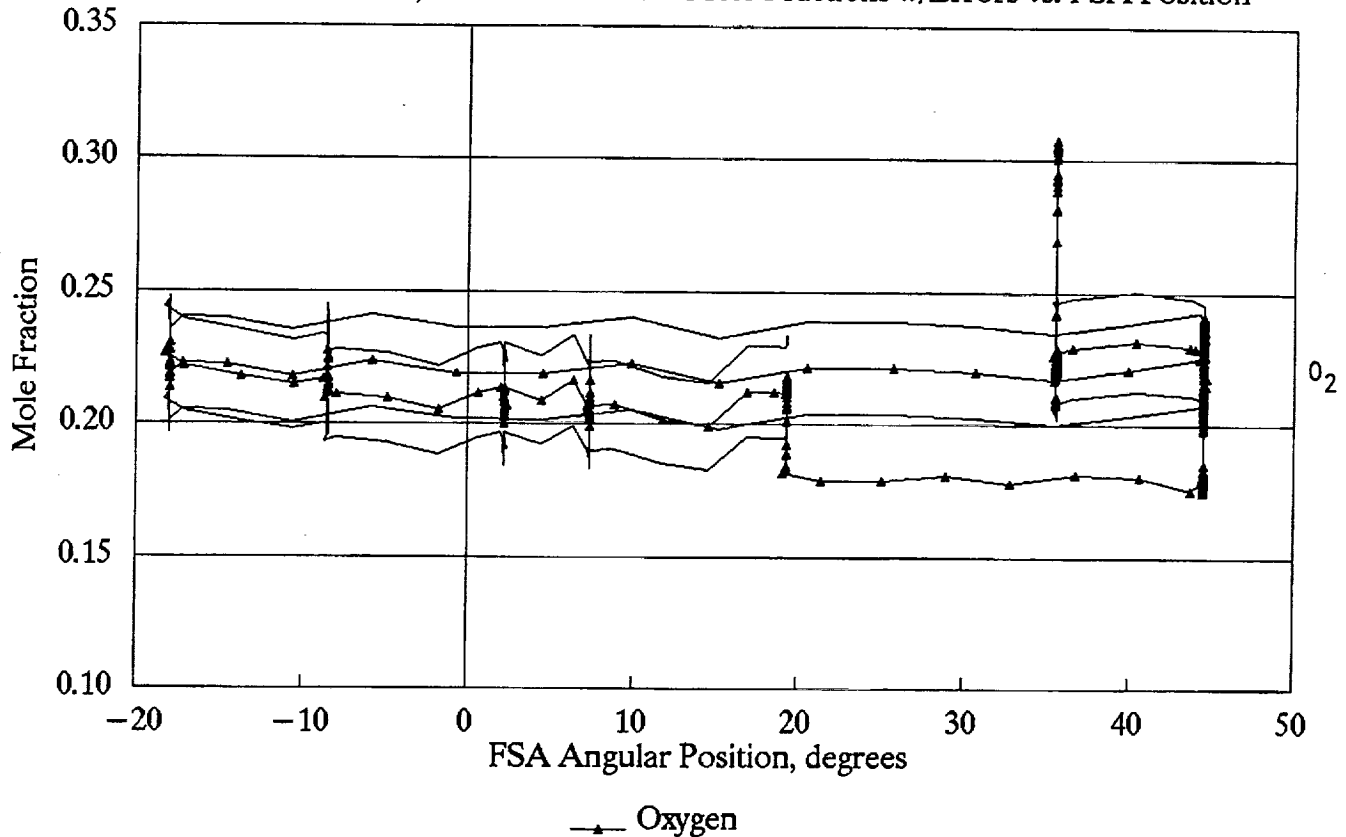
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Nitrogen:	0.491	+/-	0.021
Oxygen:	0.214	+/-	0.015
Argon:	0.008	+/-	0.001
Carbon dioxide:	0.093	+/-	0.008
H2O:	0.185	+/-	0.014
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA +1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

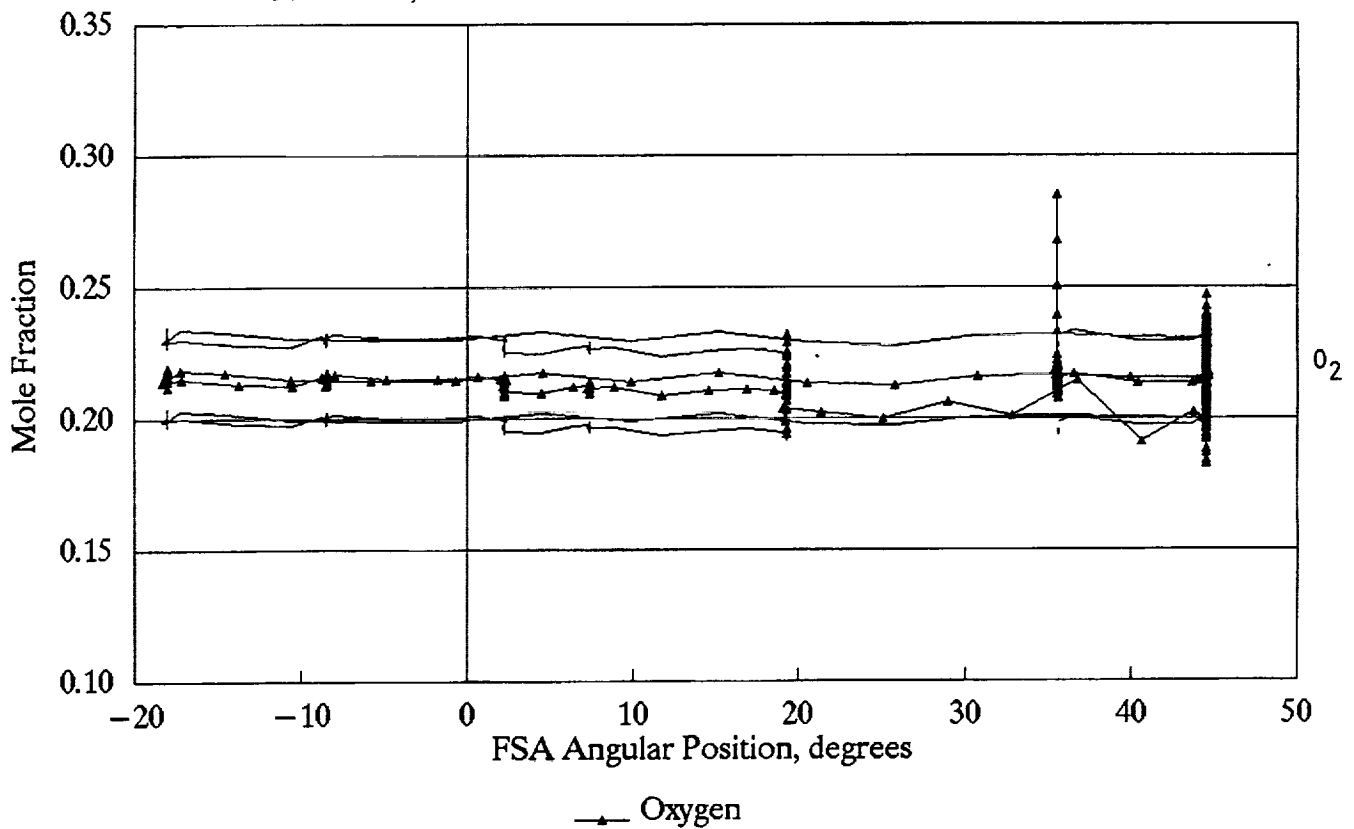
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.215 +/- 0.017

8' HTT Gas Analysis System

Test 139 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

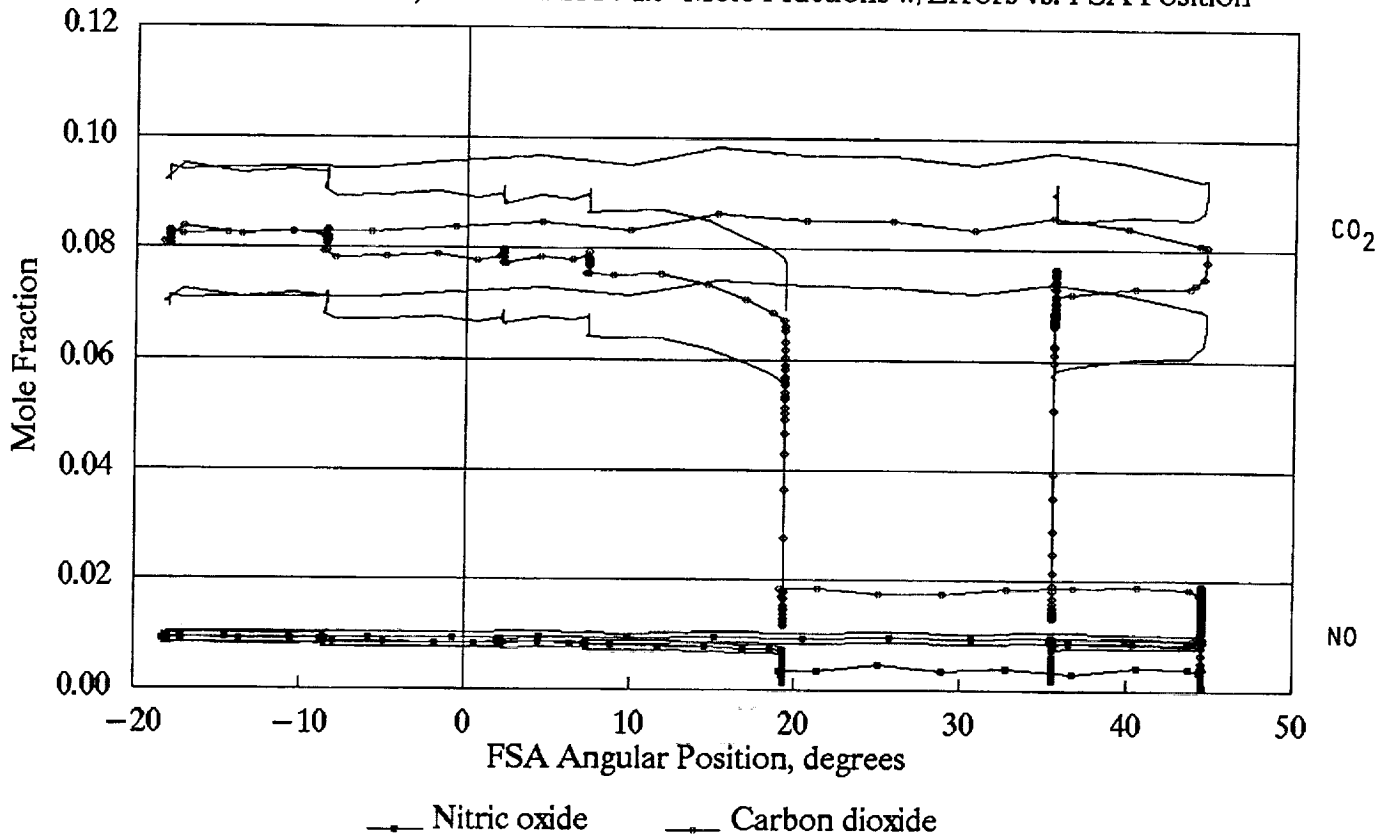
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Oxygen: 0.214 +/- 0.015

8' HTT Gas Analysis System

Test 13.9 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



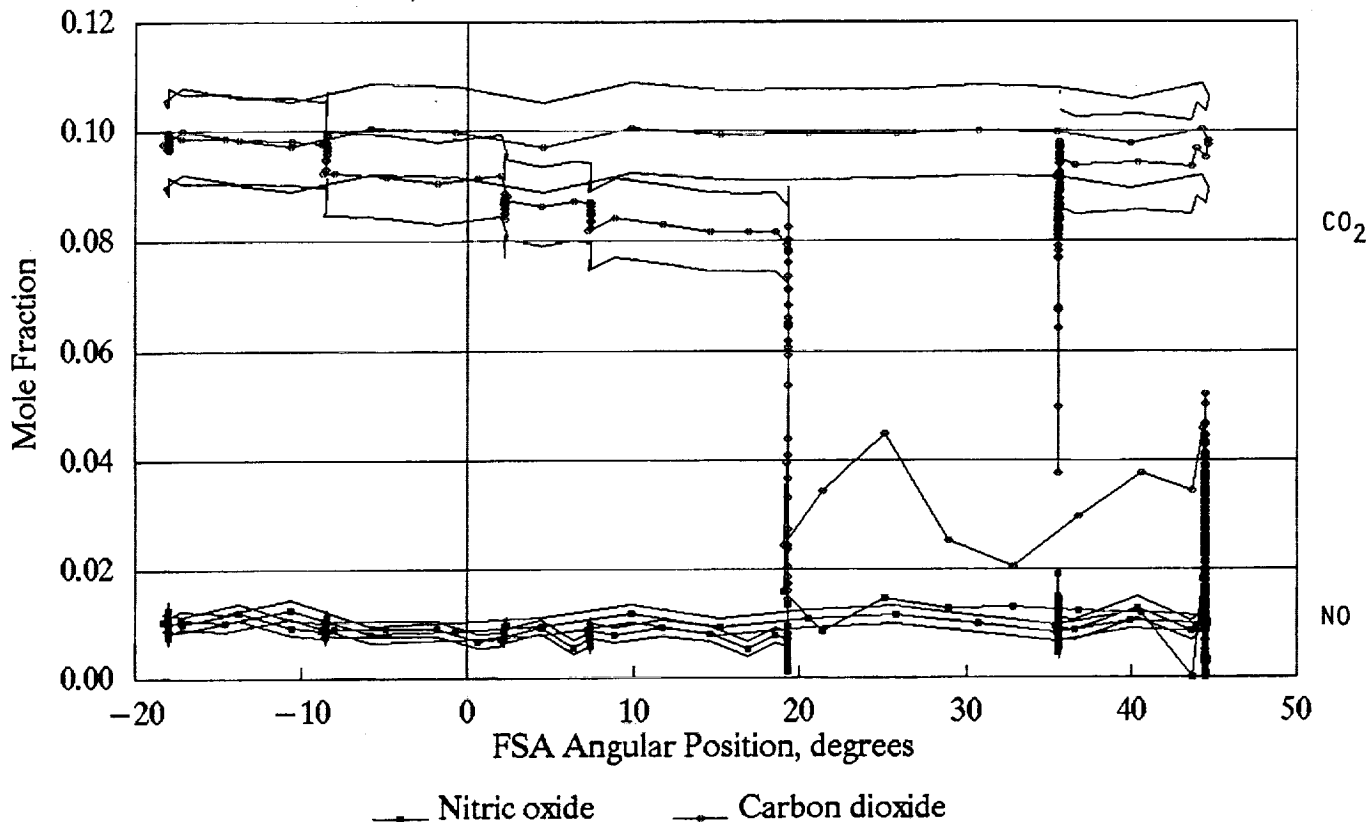
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.081	+/-	0.011
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 13.9 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

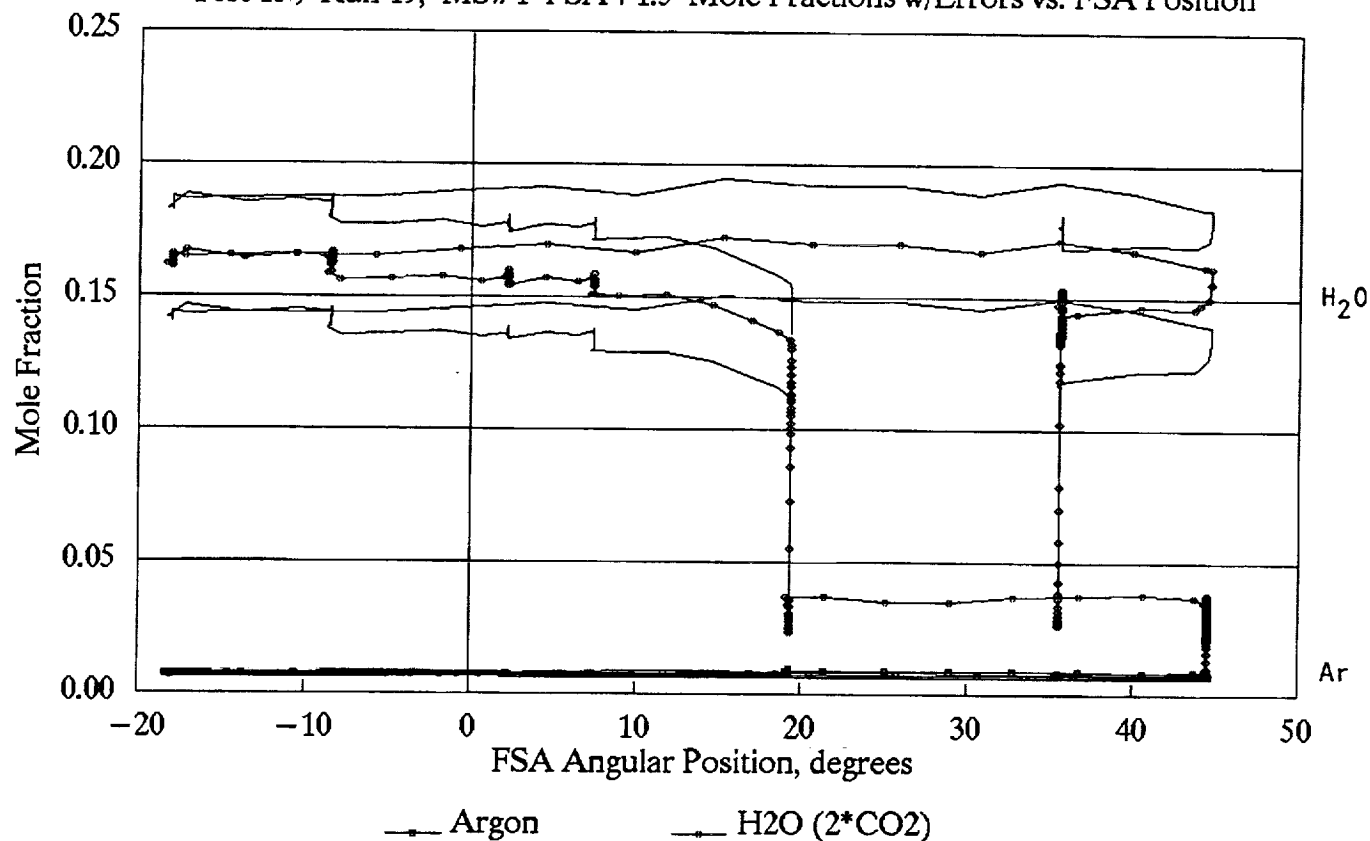
CO₂ fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Carbon dioxide:	0.093	+/-	0.008
Nitric oxide:	0.009	+/-	0.001

8' HTT Gas Analysis System

Test 139 Run 19, MS#1 FSA+1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

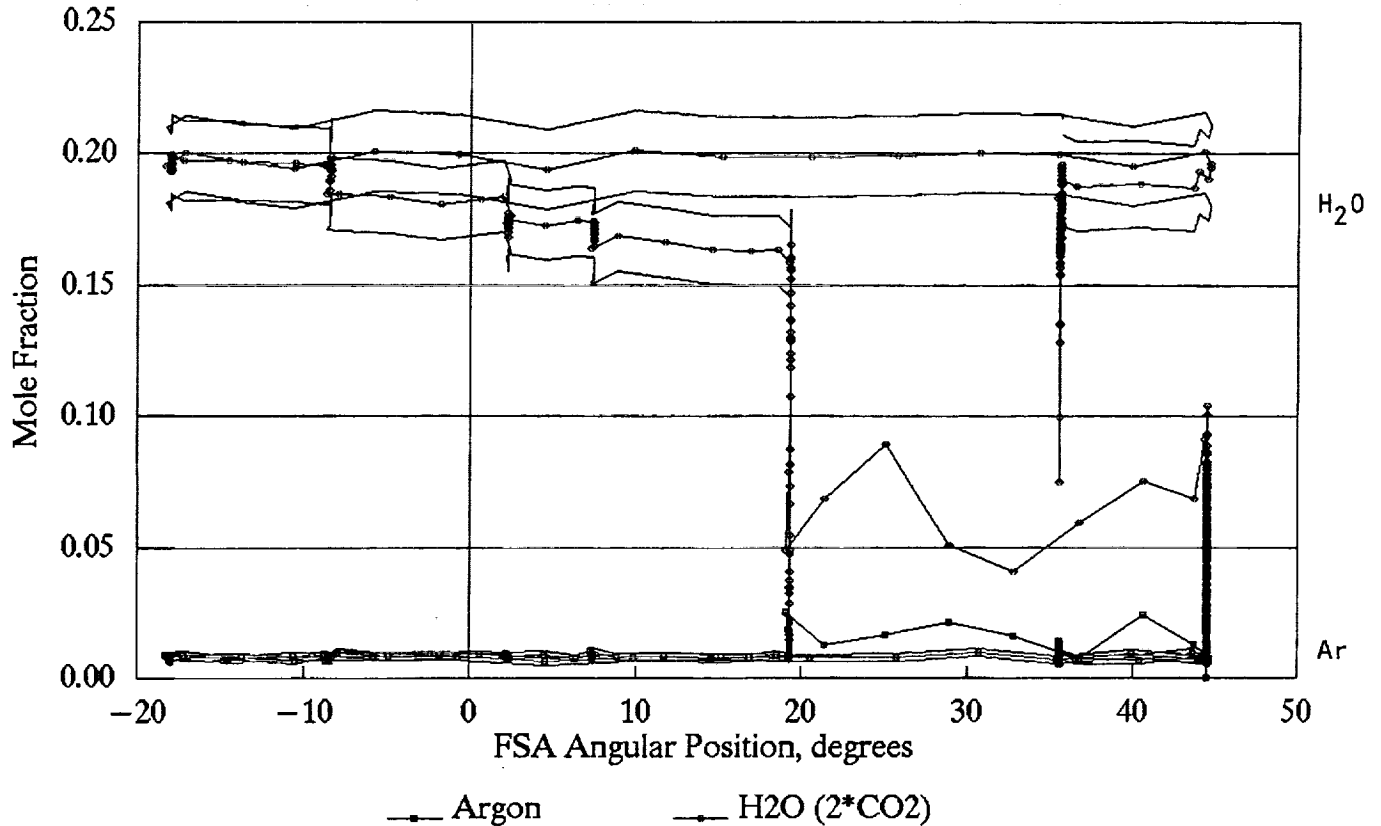
CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.007	+/-	0.001
H2O:	0.161	+/-	0.021

8' HTT Gas Analysis System

Test 13 9 Run 19, MS#2 FSA-1.5 Mole Fractions w/Errors vs. FSA Position



Errors given at 95% level of confidence.

CO2 fragmentation coefficient: 0.0817.

Mole Fractions, averaged from 155 to 170 seconds:

Argon:	0.008	+/-	0.001
H2O:	0.185	+/-	0.014

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13. ABSTRACT (Maximum 200 words) This report presents results of gas analyses of Mach 7 Tunnel Calibration Test 139 conducted in the Langley 8-Ft. HTT from May through June of 1998. These tests in support of hypersonic airbreathing propulsion provided a current calibration at the primary test condition for the National Aero-Space Plane Concept Demonstration Engine and a new calibration for the two test conditions that will be used for engine testing in support of the Hyper-X program. Samples taken from three probes on the Flow Survey Apparatus were analyzed using mass spectrometers. Although this wind tunnel doesn't produce a true simulation of flight conditions, test results show that a uniform oxygen concentration of 21 percent was achieved.				
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